13 Strategies for Achieving Zero Solid Waste in the United States by 2050

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Introduction

Overview

We are innovating to fundamentally change the way humans create and use physical objects. At the moment, we create in order to use and eventually dispose. Our world has been driven and shaped by supply, demand, and consumption, but with 7.5 billion inhabitants on this planet our waste practices are unsustainable. We have the opportunity to change how we interact with waste.

Our goal in this report is to reframe the solid waste conversation in the U.S. We will plot the innovation and changes that will happen culturally, technologically, scientifically, politically, and economically to show how we can realistically become a country that, by 2050, diverts 100% of our solid waste from landfills and incineration.

Background

In 1950, the world's population was 2.55 billion (Rosenberg, 2017). Today, it is 7.58 billion (Worldometers.info, 2017). Meanwhile, per capita consumption, as measured by global energy increase divided by population increase, has increased two-fold (Heinberg & Fridley, 2016). To make factors worse, we are increasing the rate at which we diminish our stock of finite natural resources and harvesting our renewable natural resources faster than they can regenerate. And, a sobering projection is that the human population is expected to reach 9.8 billion by the year 2050 (Held, 2017).

In the United States (U.S.) alone, on average, each person generates just shy of one ton of municipal solid waste per year (USEPA, 2016a). This does not even begin to take into account the amount of waste generated by industrial sources that produce the products we use.

This magnitude of waste is especially problematic given that many of the resources we are consuming at such an alarming rate are not renewable on a human timescale. An increasing human population means that more and more individuals are demanding their share of these finite resources. Additionally, much of the waste we produce ends its life in landfills and oceans, which leads to contamination of groundwater, the release of harmful methane gases, toxic and carcinogenic chemicals in the food chain and habitat destruction.

Luckily, there are many ways to turn what might be considered waste and discarded somewhere out of sight, into material that can go back into the economy to create new products. This allows our finite resources to be reused, which helps take the strain off the natural stocks we still have in the earth. SInce 1980, the recycling rate in the U.S. has gone up threefold and today sits at roughly 30% (USEPA, 2016a).

While this is a great start and a great improvement, it is far from what it needs to be. To develop as a truly sustainable civilization, we need to create plans that allow us to advance in accord with the Brundtland Report's definition of sustainable development, as set forth in 1987: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987).

Defining "Zero Waste"

Our first step for this investigation was to create an operational definition of zero waste which we could use to guide our research. The Resource Conservation and Recovery Act (RCRA) (1976) which provides an overarching framework for waste management in the U.S. defines solid waste as "...any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, resulting from industrial, commercial, mining, and agricultural operations, and from community activities…" (USEPA, 2017g). The RCRA includes additional regulations for hazardous wastes and also excludes certain wastes that would otherwise be considered solid including: domestic sewage, radioactive waste and others (USEPA, 2017g). For the purpose of this paper, we consider solid waste to be municipal solid waste (MSW), "...(also called trash or garbage)...defined at the national level as wastes consisting of everyday items such as product packaging, grass clippings, furniture, clothing, bottles and cans, food scraps, newspapers, appliances, consumer electronics, and batteries. These wastes come from homes; institutions such as schools and hospitals; and commercial sources such as restaurants and small businesses. EPA's definition of municipal solid waste (MSW) does not include municipal wastewater treatment sludges, industrial process wastes, automobile bodies, combustion ash, or construction and demolition debris" (USEPA, 2017h, p. 1). The EPA's definition of MSW also excludes hazardous waste (USEPA, 2011).

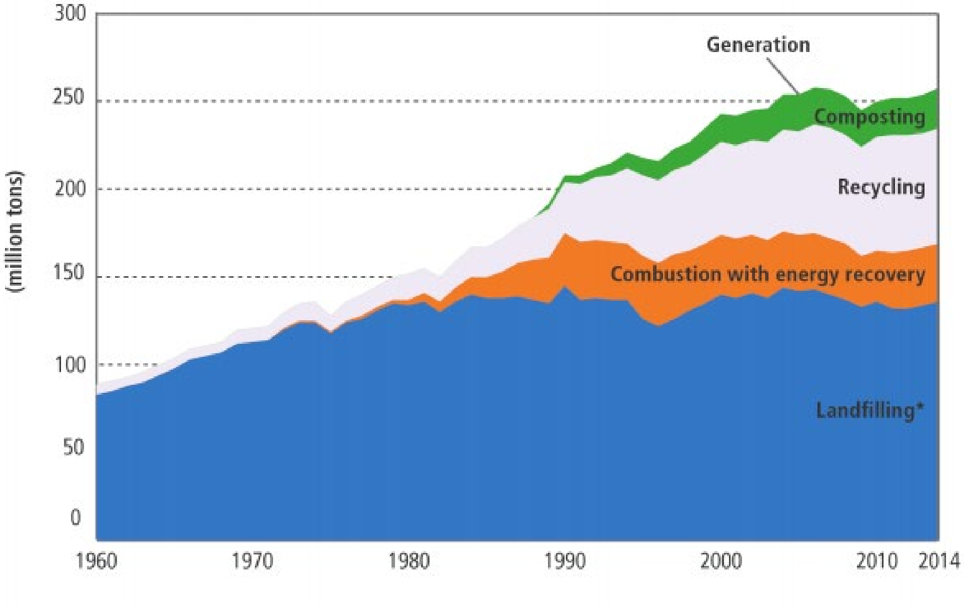
In defining "zero waste" we also wanted to consider how certain other waste disposal methods besides landfilling can also be harmful to the environment and create situations of environmental injustice. To that end, we decided to exclude incineration and exportation from consideration as diversion strategies. Certain industrialized nations like the U.S. export solid waste to developing nations where environmental regulation is less stringent and the cost of disposal cheaper, often times leading to waste dumping in or near marginalized communities (Ajibo, 2016). According to the most recent study by the Institute of Scrap Recycling Industries (ISRI), "...approximately 26.36 percent of the scrap materials processed in the U.S. are exported to other countries" (Carpenter, 2017). While much of this export is recycled into new products that are then shipped back to the U.S., oftentimes recyclables are contaminated with other sorts of solid wastes which can lead to human and environmental health problems (Braden, 2017). In a recent filing to the World Trade Organization (WTO), China argues for restrictions on imports of certain solid waste categories and states that "[w]e found that large amounts of dirty wastes or even hazardous wastes are mixed in the solid waste that can be used as raw materials..." (Braden, 2017). Incineration of MSW has been shown to release high levels of chemical compounds called dioxins that are harmful to human and environmental health (Zafar, 2008). Therefore in keeping with the above limitations, our definition of zero solid waste is: one hundred percent of U.S. domestic MSW (as defined by the EPA) diverted from landfilling, incineration and exportation.

Waste Management in the U.S.

Once we had defined zero waste within the context of our project, we set about building an understanding of the current state of waste management in the U.S. In 2014 there were 1,908 landfill facilities in the U.S. (USEPA, 2016b). In 1960, 93.6% of waste generated in the U.S. was sent to landfills or incinerated without energy recovery and only 6.4% was diverted for recycling (**Fig. 1**) (USEPA, 2016b). In 1960, the U.S. generated 88,120 thousand tons of municipal solid waste (USEPA, 2016b). In 2014, this number had risen to 258,460 thousand tons of municipal solid waste per year (USEPA, 2016b). Not only is the country as a whole producing more waste than ever, but each person is producing almost twice as much waste on average than 50 years ago: in 1960, the average U.S. citizen generated 2.68 pounds of solid waste per day, in 2014, the average was 4.44 pounds of solid waste per person per day (USEPA, 2016b).

It isn't all bad news though. Although Americans generated nearly twice as much municipal solid waste per person per day in 2014 than they did in 1960, much less of the waste ended up in landfills than would have half a century ago (USEPA, 2016b). Whereas in 1960 over 93% of waste was disposed of in landfills, in 2014 just over 52% of MSW was sent to landfills (**Fig. 1**) (USEPA, 2016b). That's a big improvement in the course of 50 years but it's still only halfway to our goal of 0% of waste being disposed of in landfills.

While diversion strategies have expanded in scope in the past 50 years, the U.S. still sends a constant amount of waste to landfills (**Fig. 1**). To achieve zero waste, the total amount of waste would need to be reduced (through source reduction) and diversion strategies would need to grow in order to capture the entire amount of waste created.



*Landfilling after composting, recycling and combustion with energy recovery. Includes combustion without energy recovery.

Figure 1. Municipal solid waste disposal methods from 1960 to 2014 (USEPA, 2016b).

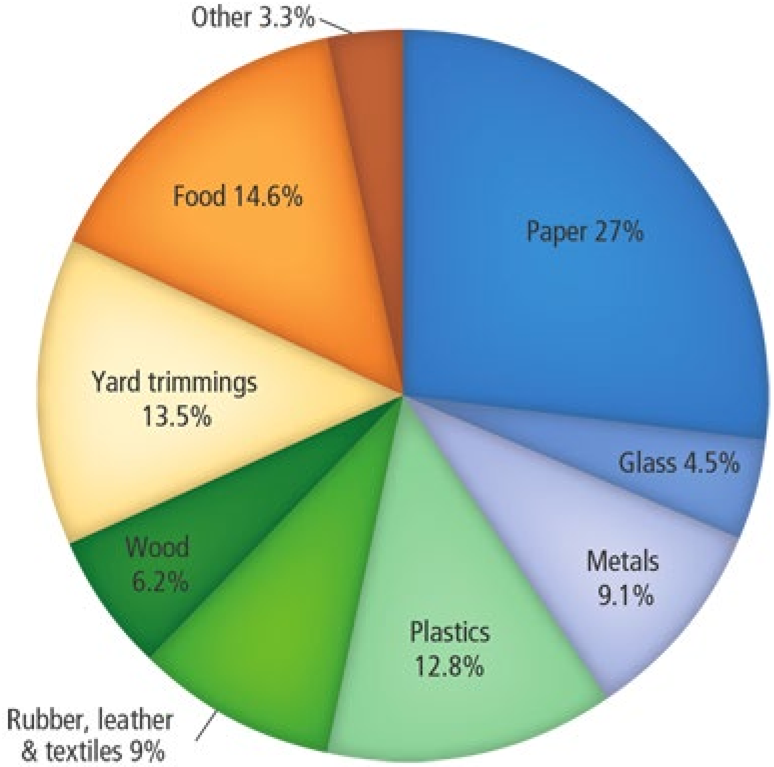


Figure 2. Total U.S. municipal solid waste generation by material in 2013 (USEPA, 2016a).

Compartmentalizing the Waste Problem: Biological vs. Technical Nutrients

After we had established a baseline of context for waste in the US, we wanted to find a way to break down our broad problem into smaller ones that we could tackle. After reading McDonough and Braungart's book *Upcycle,* we found the first step. McDonough and Braungart posit that all waste can be divided into one of two categories: biological and technical nutrients. Biological nutrients are biodegradable and can be recycled endlessly by the biosphere through the process of decomposition. Technical materials are everything else, like plastic or glass. Under the current system in the U.S., both biological (wood, paper, yard trimmings, food etc.) and technical nutrients (metals, glass, plastics etc.) are collected and disposed of together in the municipal solid waste stream **(Fig. 2)**. In an ideal world, these two kinds of materials would be separated into their own closed-loop cycles in which they could be continuously cycled and regenerated for use (**Fig. 3.**).

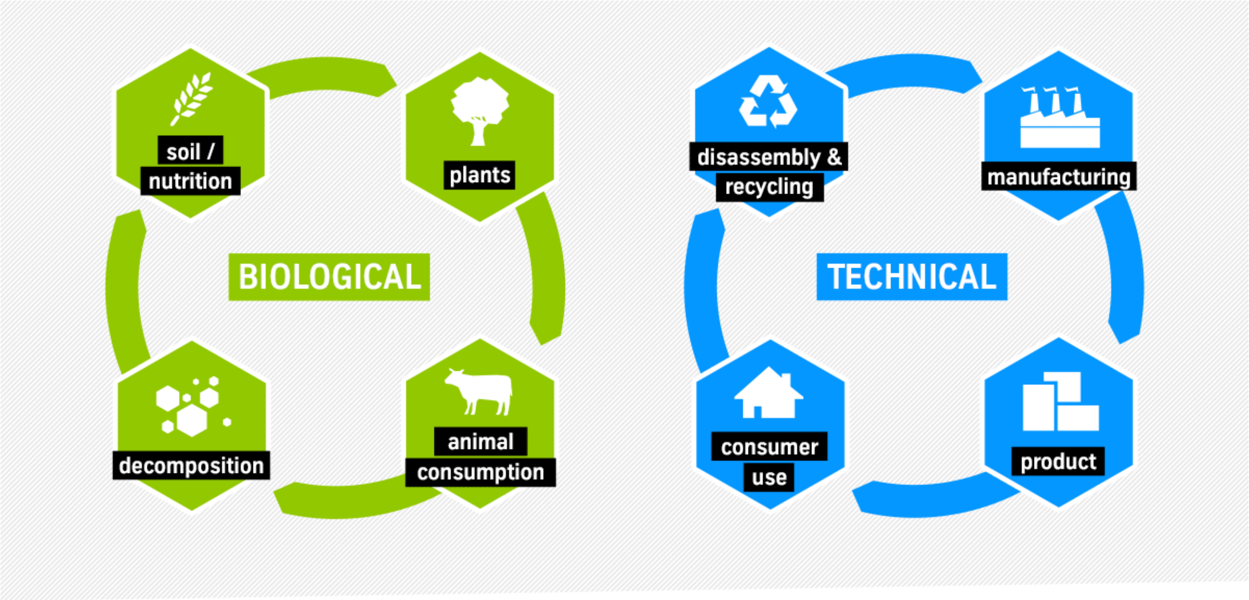


Figure 3. Biological and Technical nutrients are recycled endlessly in separate biological and technical cycles (Urban Hub, 2017).

We used the *Upcycle* concept of separate biological and technical nutrient cycles as our first division of solid waste. Our next step was to break down the problem further into mutually exclusive and completely exhaustive (MECE) strategies which would divert 100% of solid waste from landfills. To do this we used the EPA's Food Waste Hierarchy (**Fig. 4A**) and non-hazardous materials and waste management hierarchy (**Fig. 4B**) as a guide for creating two hierarchies of the most promising strategies for diverting 100% of biological and technical nutrients from landfills by 2050. Thus, the remainder of this report will be divided into two sections: in the first we will explore five strategies for diverting biological nutrients from landfills, and in the second section we will explore some parallel strategies for diverting technical nutrients from landfills. In order of most to least preferable, our strategies for diverting biological nutrients from landfills are: source reduction, redistribution, feeding animals, composting and anaerobic digestion (**Fig. 5A.**). Our parallel technical nutrient strategies are: source reduction in the form of a virgin raw materials tax, product stewardship, repurposing through single stream recycling and decreasing generation of toxic materials (**Fig. 5B.**). In the final section of this report we will explore three additional strategies focused around education. These educational strategies could be enacted alongside our diversion strategies in order to increase awareness of the problem and participation in the solutions.

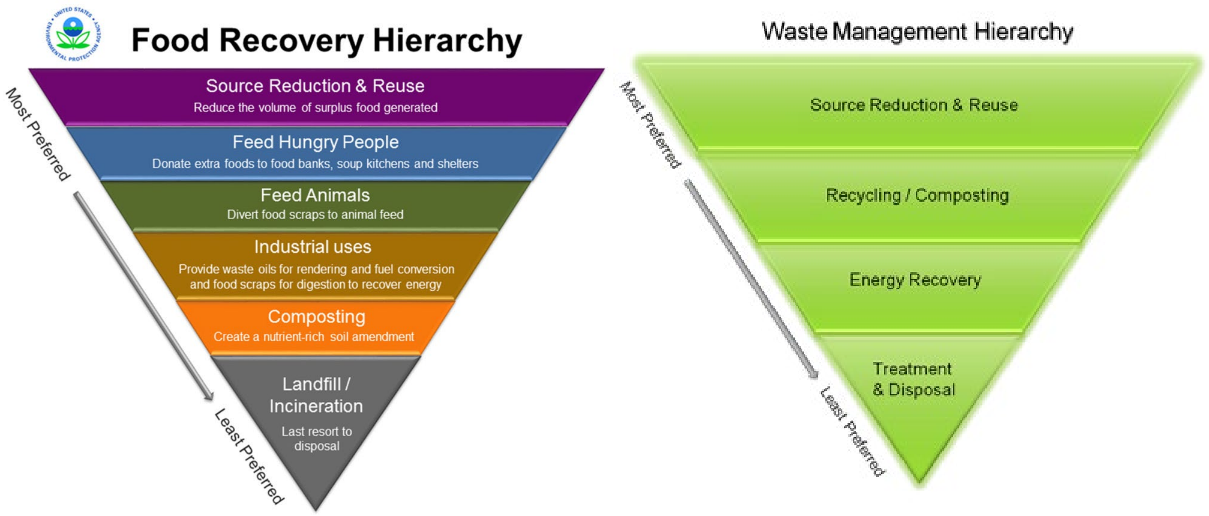
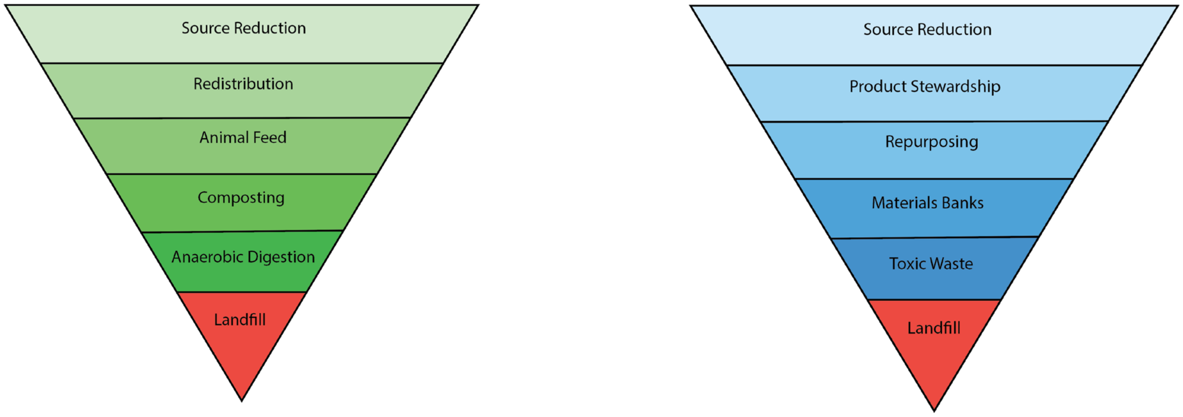

Food Recovery Hierarchy
Source Reduction & Reuse
Reduce the volume of surplus food generated
Feed Hungry People
Donate extra foods to food banks, soup kitchens and shelters
Feed Animals
Divert food scraps to animal feed
Industrial uses
Provide waste oils for rendering and fuel conversion and food scraps for digestion to recover energy
Composting
Create a nutrient-rich soil amendment
Landfill / Incineration
Last resort to disposal
Most Preferred
Least Preferred
Waste Management Hierarchy
Source Reduction & Reuse
Recycling / Composting
Energy Recovery
Treatment & Disposal
Most Preferred
Least Preferred

Figure 4. The U.S. EPA **A)** Food Recovery Hierarchy (USEPA, 2017a) and **B)** non-hazardous materials and waste management hierarchy (USEPA, 2017b).



A) Biological Nutrient Diversion Hierarchy **B) Technical Nutrient Diversion Hierarchy**

Figure 5. Solid waste landfill diversion strategies for **A)** Biological nutrients and **B)** Technical nutrients. Based off the EPA's Food Waste Hierarchy (USEPA, 2017a) and non-hazardous materials and waste management hierarchy (USEPA, 2017b).

Format Overview

For each strategy, we begin with a general overview based in the current literature on the subject including a summary of the social, environmental, economic and political benefits and necessary conditions for each strategy within the U.S., which we shorthand as the "SEEP analysis". Next we explore a case study in which the strategy was successfully implemented. Though our focus for this report is achieving zero waste within the U.S., we draw on case studies from all around the world. We conclude each strategy report with a section in which we project forward to 2050 and extrapolate from both the overview and case study what sorts of SEEP conditions would have had to been met in order for the strategy to scale up as a major factor in achieving zero waste in the U.S. In this section we will speak in the present tense as we conjecture how each strategy might play a role in a waste free society.

SECTION 1: Biological Nutrients

Introduction

Organic materials make up approximately 56.3% of municipal solid waste (MSW) (Zannolli, 2012). Broken down even further: paper products, food scraps and yard trimmings accounted for 29%, 13.9% and 13.4% respectively of all municipal solid waste in 2009 (Zannolli, 2012). The U.S. roughly parallels the global rate of food waste with "...31 percent-or 133 billion pounds-of the 430 billion pounds of the available food supply" going uneaten in 2010 (Buzby et al., 2014, i). According to the EPA, "[i]n 2014 alone, more than 76 billion pounds of food waste was generated, with only 5.1 percent diverted from landfills and incinerators for composting" (USEPA, 2017c).

In our current system, food waste is primarily disposed of through incineration, landfilling or through the sewage system via a garbage disposal (Heller & Keoleian, 2003). However contrary to this apparent abundance of excess food in the U.S., the USDA reported around the same time that "...approximately 13 percent of American households had difficulty providing enough food for all their members due to a lack of resources at some time during 2015" (USEPA, 2017a).

Food waste isn't just bad for the environment and food insecure families and communities, it is a huge source of wasted economic gains as well. In 2010 the estimated retail value of food wasted in the U.S. was $161.6 billion (Buzby et al., 2014, i). That's more than the individual GDP's of the 135 poorest countries in the world (International Monetary Fund, 2017 as cited in StatisticsTimes.com, 2017).

The Food and Agriculture Organization of the UN estimates that industrialized nations waste 210-150 lbs of food per person each year (Gustavsson et al., 2011, v). In developing nations this figure may be as low as 13-25 lbs per person each year (Gustavsson et al., 2011, v). Whereas in developing countries food waste is typically caused by technical limitations in harvesting and storage capacity; in developed countries like the U.S., food waste is primarily a product of consumer behavior and occurs primarily at the consumption level (Gustavsson et al., 2011, v).

This is not breaking news by any means, the United States Environmental Protection Agency (U.S. EPA) has long acknowledged that "[r]educing wasted food is a triple win; it's good for the economy, for communities, and for the environment" (USEPA, 2017c). Pursuant of the goal of reducing food waste, the U.S. EPA has created a Food Recovery Hierarchy (**Fig. 1**) of most to least preferable strategies for reducing food waste based on which "create the most benefits for the environment, society and the economy" (USEPA, 2017a). A nearly identical food waste hierarchy shows up in the European Parliament Council's 1975 Directive on Waste (Papargyropoulou et al., 2014).

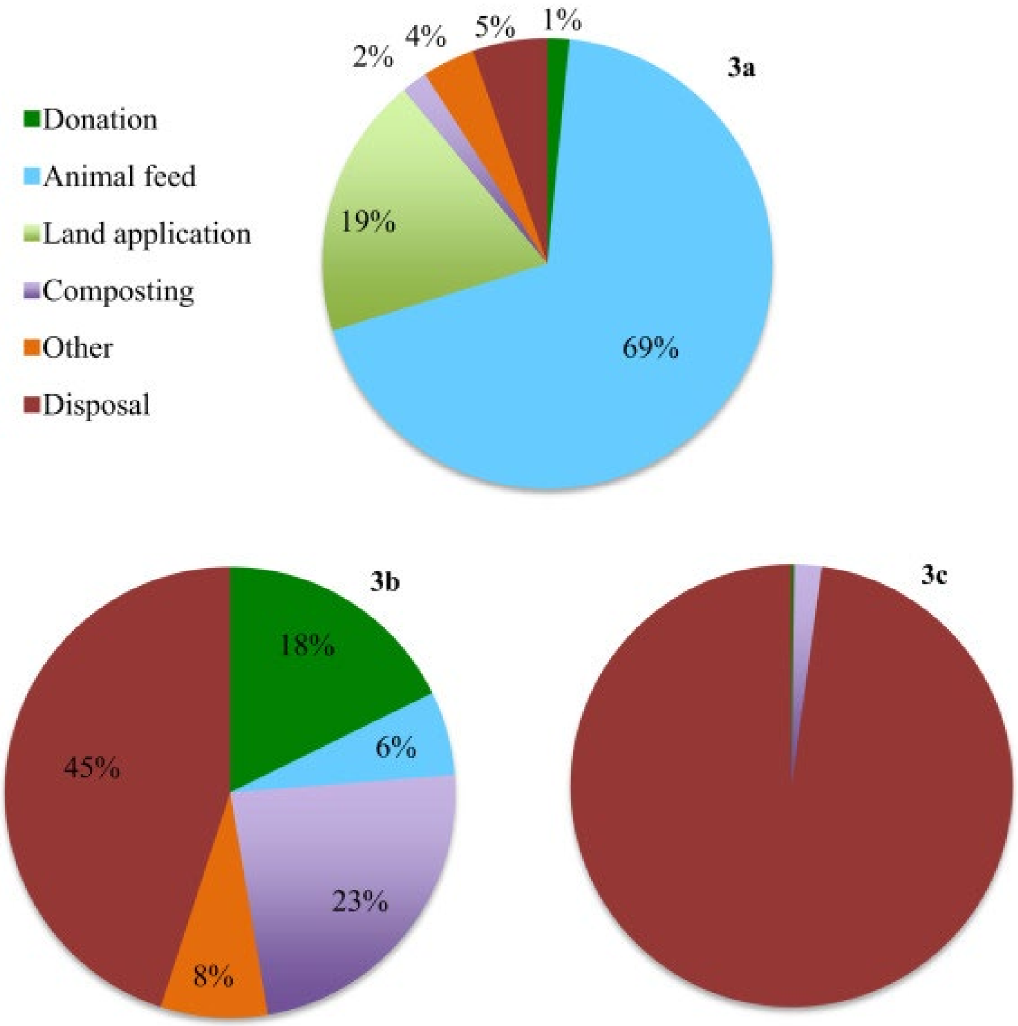


Figure. 6. Food waste disposal strategies in the **a)** manufacturing, **b)** retail/wholesale and **c)** consumer sectors (Dou et al., 2016).

Food waste occurs in three sectors of the supply chain: manufacturing, retail/wholesale and consumer (Dou et al., 2016). The unique characteristics of the food waste stream in each of the three sectors results in different food waste management strategy profiles. Almost 70% of the food waste generated in the manufacturing sector is fed to animals, whereas in both the retail/wholesale and consumer sectors disposal is the most common strategy (Dou et al., 2016) (**Fig. 6**). The three sectors are also distinct in the amount of food waste they generate each year. While the manufacturing and retail/wholesale sectors generate 20.1 million megatons and 1.7 million megatons of food waste per year respectively, the consumer sector produces approximately 90 billion pounds of food waste per year (Dou et al., 2016). Not only does the consumer sector generate the most waste, but it also sends the vast majority of that waste to landfills (**Fig. 6C).** For this reason, we have identified the consumer sector as a priority area for waste diversion. In our first strategy, source reduction, we tackle the root of the food waste problem in the U.S. by focusing on changing consumer behavior.

Strategy #1: Change Food Waste Mindset (Reducing Avoidable Food Waste)

Overview

Food waste is a problem that needs to be tackled at every step of the chain. The issue is not only moral as food is wasted at the same time people go hungry, but also environmental and economic. At least 25% of the world's farmland is used for food that does not get eaten (Smith, 2014). While producers currently produce twice the amount of food that is actually needed, they are not creating the problem. What drives the problem is a disconnect between what we deem suitable to eat and what, in reality, is. More than half of the food we throw out is perfectly fit for consumption (Sembrat, 2017). As consumers, we have been conditioned - by jumbo sized packages, by confusing "sell-by" dates, by industry that makes food hyper-cheap, by supermarkets' placement of food, and by culture - to seek out and buy aesthetically "perfect" foods (Royte, 2014).

While the restaurant industry is partially to blame for food waste, two thirds of the food consumers waste is in the home (23 pounds per person per month!) (Ferdman, 2014). A recent study in southern Sweden showed that "an average of 35% of household food waste is avoidable" (Schott & Anderson, 2015). In the 1970s, we wasted half the amount of food we do now; our mindset has changed since then for the worse. Younger generations are more to blame for food waste for a number of reasons. The primary culprit is time. Time-poor full-time workers, or families with two parents that work, buy too much food and then throw it away (Smithers, 2017). Further exacerbating the issues is the "Instagram generation" that focuses too much on food's appearance. These millennials have higher grocery bills, more waste, and are less comfortable in the kitchen than older generations, underprepared to reuse ingredients that are leftover (Smithers, 2017).

To change how we interact with food, we need to change the conditions that set up our behaviors that lead to food waste. There are market and social conditions that make wasting food too easy and a habit. We must look into the psychology of behavior change to address our faulty aesthetic perceptions of food. As Michie et. al (2011) lays out, to change a behavior, one must address the three sources of behavior: 1) capability, 2) opportunity, and 3) motivation. All three are necessary. If the right opportunities are presented, we can create a context in which behavior change is natural.

To change our motivation to buy more food than we need, we should consider changing the price of food. If the price of food reflected the *actual* cost of what it took to create it, people would have more of an incentive to not waste food. This strategy is aimed at source reduction; the effect of eating a higher percentage of the food produced would reduce the need to produce as much food. If we reduce demand….The source would eventually produce less, using less resources and land. Food is heavily subsidized in the U.S. and, because of this, wasting food does not have a proportional financial impact. Many Americans are thrifty and work on a budget, but food is not expensive enough to prevent food waste or make people consider how much food they are purchasing.

Next, we need to change our capability, according to Michie. As discussed, Americans are time-poor. We do not do a good job of planning grocery lists to purchase exact amounts of what we need and end up erring on the side of buying too much (Smithers, 2017). Thus, this leads us to buy more food than we need and throw out what is left over. If Americans had the skills and capability to waste less food, it would be easier to do so. Americans need to make or find the time to develop food planning and preparation skills. Many are unskilled cooks because fast food is cheap and easy. If cooking were taught in schools and children learned to use all parts of a food item, there would be less thrown out. Furthermore, we need more initiatives that get this information out to hard-to-reach populations. Leftovers can be repurposed, but too often are not. Everyone can learn how to use older vegetables in a soup or the hard parts of a vegetable to make broth. At this point, though, people don't even know where to look. As a country, we need to "take back" our kitchens from this waste land of how we nourish ourselves via food - we need to build a culinary common sense. This information needs to be accessible.

The myths of sell by dates or best by on labels leads many Americans to throw out food that they are unsure about eating. Americans need to shift what they consider to be "OK" to eat. Labeling is an issue that needs to be tackled. Label confusion can account for up to 20% of food that gets thrown out in homes and even more food that gets wasted in supermarkets by confused shoppers (ReFED, 2017). Americans need to be educated on what "sell by" and "best by" labels mean. They are not indications of how safe food is; rather, they are indicators of how long the food has been around (Husted, 2014). Of the less food that got produced, more would get eaten.

Changes require leadership. The countries that have experienced the most success in publicizing and improving the food waste issue have had individuals deeply committed to the cause (Royte, 2014). Individuals or "champions" can create tipping points through public campaigns that lead governments and businesses to pay attention. In the US, this movement has started; a number of filmmakers, famous chefs, and non-profits have publicized the issue; institutions are taking note. Many colleges have already done away with trays that lead students to take too much food. TGI Fridays, the restaurant chain, shocked at the amount of food its customers wasted, reduced portion sizes (Rotye, 2014). The USDA has created a "U.S. Food Loss and Waste 2030 Champions" group with businesses committed to reducing food waste in their own operations with a goal of reducing food waste by 50% by 2030. The momentum needs to continue; there are still many in the U.S. without the capability, education, and motivation to reduce their own food waste. Americans are beginning to get more self-aware and are realizing that, as a country, we waste an inordinate amount of food. Food waste reduction can become an everyday regularity.

Social

The social consequences of food waste is huge: food goes into the trash that could be going to feed others. If we put less food directly into the trash, that food would be able to be redistributed to those in need.

Environmental

While there are environmentally sound strategies for dealing with food that has been produced but will not be consumed like composting or anaerobic digestion, it is important to start all the way upstream and reduce the amount of food we produce. Preventing food waste results in less greenhouse gas emission than disposing of wasted food through either incineration or anaerobic digestion. The food that we waste produces so much greenhouse gas that, if food waste were a country, it would be the third largest producer of greenhouse gas in the world (after the U.S. and China) (Smith, 2014). Furthermore, if the U.S. wasted less food, producers would not need to produce as much food, saving time, energy, water, and money.

Economic

Food waste is not only bad for the environment, but also for our wallets. The average family throws away $1,500 worth of food each year; this money could be saved with a shift in our mindset leading to a shift in our behaviors. To change the amount of food wasted, food prices should accurately represent the cost. Accurate pricing would deter Americans from wasting food.

It is currently better for supermarkets to dump out food that is past its “sell-by” date, which actually indicates peak freshness, than it is to sell at a discounted price. Produce on sale undercuts full-price stock. If we were equally happy to buy food that is still edible but past its sell-by date, supermarkets would not have this conundrum (Rotye, 2014).

Political

Politics will need to play a large role in changing food waste. Expiration labels need to be standardized to help the 90% of Americans who have wasted food because of label confusion (NRDC, 2013). Food subsidies need to decrease drastically so that Americans realize the financial impact of wasting food. Powerful lobbying groups keep supply high, prices low and money concentrated in an industrial food and agriculture system that favors behaviors that contribute to the food waste problem (Riedl, 2002).

Case Study: Denmark

In Denmark, food waste has been reduced by 25% in the past five years. There are a number of initiatives that have played a role, but one, Stop Spild Af Mad (SSAM, “Stop Wasting Food” in English), an organization founded in 2008 by Selina Juul, is often referred to as the catalyst. Juul was a Russian immigrant who had been struck by the amount of food Danish people wasted when she arrived in Denmark. She has been credited with getting food waste onto the agenda for the last three Danish governments. Since 2008, the topic of food waste has become an everyday topic of conversation; both grassroots movements, like Juul's, and government initiatives have led to an increased awareness of how much food Denmark wastes and how to change it (Bloom, 2016).

SSAM has a number of campaigns in Denmark to help people waste less food. There is an online Knowledge Center that collects data on food waste. There is an education campaign for schools on how to stop food waste; the materials have been downloaded by more than 4,900 teachers (SSAM Education Campaign, 2017). These have reached thousands of kids in the country in many schools. The group has also collaborated with the EU and the UN. They have made Doggybags more readily available throughout the country; Denmark had not traditionally had a culture of bringing home leftovers from restaurants. Stop Spild Af Mad has penned Op-Eds, collaborated with politicians, held events, created a food-waste food label, and written in a number of publications (SSAM, 2017).

The organization has a number of resources online and for people to use. The group tells consumers how to use food that is already in the refrigerator instead of going out to buy more. Buying more costs more money; they frame it in economic terms to encourage people to save money. It also encourages a "flow" in the fridge that places older foods at the front to show that they should be eaten. Likewise, leftovers should be placed centrally in the fridge to remind one to eat them (SSAM Projects, 2017).

Stop Spild Af Mad reframes leftovers. As "free bonus food"! This new attitude makes leftovers a true positive; they save a trip to the supermarket, save money, and save time. It also advocates for a "Empty Your Fridge Days" where you only eat what is leftover before moving on to new food.

The organization also has a plethora of strategies for consumers in supermarkets and restaurants. In supermarkets, it encourages the consumer to buy food close to its expiration date that is often discounted. Consumers can also buy any food that is put out; "ugly and wonky taste just the same". Just because a carrot has a strange shape doesn't mean it tastes any different. In restaurants, the organization encourages the consumer to check portion sizes, eat all they can take, and ask for a doggybag to take the food that was paid for home as a leftover.

Collectively, the dozens of strategies SSAM pursued have changed how the Danish perceive and waste food. Strategic campaigns created a public awareness that led to a behavioral tipping point. Once a critical mass got on board, SSAM's momentum was able to carry the issue to the national spotlight. The U.S. will need a similar grassroots movement to reach both the average citizen and our government to get the message out. This needs to happen at every scale- local citizens, states' schools, federal campaigns- and will change how we think about food.

Looking Back From 2050

Even now in the U.S. some have started to take pride in their use of "ugly" food. By 2050, it will be taboo to throw out perfectly acceptable "ugly" food. The momentum that individual champions started in the 2010s, picked up by the USDA, will lead industries and businesses to make food waste reduction more convenient across the country. In the economic realm, food prices will reflect actual costs and both businesses and consumers will be incentivized to avoid wasting food. Thanks to successful lobbying by high-profile chefs and food waste organizations, food subsidies to large farms that incorporate food waste into their strategy will end. Instead, federal programs will be launched that focus on the social implications of less food waste. Food waste education will exist across the U.S. in every school. Children will learn how to use all parts of a vegetable in class, making broths out of the odds and ends. Parents will use every part of a food item that is edible. Families will have designated “leftover” days, and the word “leftover” will no longer produce groans, but rather excitement.

Technologically, storage containers have improved, leftovers remain fresher for longer, and smart refrigerators remind families to use that leftover pasta before it goes bad. These smart refrigerators will keep track of how many pounds of food a family throws out per month, and families can compete with themselves for prizes set up through government and private sector partnerships to do better each month. A mindset change established through effective leadership, policy and economic carrots and sticks lead to a huge cultural shift that eliminates this unnecessary waste from the path our food takes.

Strategy #2: Food Redistribution

Overview

As is often pointed out, if even a fraction of the amount of food that gets wasted each year were diverted, the U.S. could make huge strides on food insecurity and potentially end hunger. While composting is a good strategy for inedible food, edible food that can be eaten should be as illustrated by our hierarchy of consumption. Edible food has a higher value than composting and can meet multiple needs. Food redistribution can happen at any stage in the consumption chain: food left out on crop fields, food not bought by supermarkets, food unsold by supermarkets, and even food in consumers’ households can be redistributed to others given the right infrastructure.

This strategy will focus most heavily on food that is left unsold by supermarkets. Household food waste, accounting for about 20% of all food waste, is tackled by another of our strategies, changing the food waste mindset, and waste further up the food chain does not amount to as much as at the supermarket, which accounts for 10% of all food waste (Husted, 2014). These two strategies will need to work in tandem with each other; supermarkets should both reduce their own waste and also make it easier for consumers to eat all food available at the location. We want to make unsellable food sellable, and whatever remains should be redistributed.

Supermarkets and restaurants generally throw out more than 100 million pounds of food each year (Husted, 2014). Consumers generally prefer displays of perfectly ripe, unblemished produce; the rest of the produce gets tossed out. This food is generally perfectly safe, nutritious, and edible, but consumers avoid foods close to expiration or produce that doesn’t meet their personal aesthetic standards. As discussed in the previous strategy, our perceptions of what food is suitable to eat are flawed.

The federal government already provides tax deductions as incentives for businesses to donate food (Harvard Food Law & Policy Clinic, 2016). There are numerous organizations that already exist that help supermarkets minimize their food waste. These organizations rescue food that is headed for the trash to redistribute it to food banks. However, there is no particular incentive for supermarkets to not throw out their unsold food.

At this time in the US, many jurisdictions have already banned supermarkets from throwing out food. If every state has laws like this, supermarket waste would be hugely reduced. While it would be impossible to get every piece of food eaten before expiration, this would be a huge step towards that. Companies would spring up to compete to redistribute food and create a redistribution economy. There could be discounted food markets that sell redistributed food at cheaper prices to those on a budget. If businesses received tax credits for avoiding food waste and feeding hungry residents nearby, we would have a win-win-win situation for the economy, the environment, and people in need.

Social

Of all the strategies mentioned in this report, food redistribution is perhaps the most important socially. Food redistribution helps to bridge the gap between those who can afford to waste food and those who cannot afford to eat. Getting food to hungry people is not only a health issue. Once a hungry person can depend on food, they can focus on other realms of their life.

Environmental

A functional, large-scale food redistribution, in tandem with changing our food waste mindset, would make it unnecessary to produce as much food as we do. We produce more food than is necessary in the US. If we created efficient systems for redistributing it, we would not need to produce more food than can be eaten. Less production means less greenhouse gases into the atmosphere. On top of that, redistributing food can prevent food from going into landfills. Without food in them, landfills would not produce dangerous amounts of methane.

Economic

Redistributing food is good for the economy. It creates jobs and reduces waste. It creates a more efficient, closed-loop system. By redistributing food that would be thrown out, the government can save on programs that feed those who would otherwise receive redistributed food.

Political

Food redistribution is a smart choice politically. If it becomes illegal for supermarkets to throw out edible food, food redistributors can step in to help. The government can offer incentives to organizations involved and help private redistributors get started.

Case Study: Lovin' Spoonfuls

One successful example of a food redistribution organization is Lovin' Spoonfuls based in Boston, MA. The food rescue is a 501(c)3 nonprofit that has rescued more than 7.5 million pounds of food that has fed half a million people since 2010 (Lovin' Spoonfuls, 2017). The company is "the bridge between abundance and need", redistributing healthy, fresh food that is otherwise headed for the trash. The company currently relies on grants and donations to support their efforts.

The company has two goals: reducing food waste and reducing hunger. Furthermore, they wish to change the conversation about food waste by educating the public and advocating for food waste reduction measures of all sorts.

The company currently has more than 70 donors that include grocery stores, produce wholesalers, farms, and farmers markets that give around 60,000 lbs of food per week. On a daily basis eight Lovin' Spoonfuls designated staff drive on particular routes in refrigerated trucks to pick up unused, edible food at donors (generally grocery stores) and deliver it the same day to nearly 140 nonprofits in the Boston area. These nonprofits include homeless shelters, soup kitchens, food pantries, senior centers, after school programs, and domestic violence agencies (Lovin' Spoonfuls, 2017).

Looking Back From 2050

In 2050, food redistribution is a fact of life. Driverless cars programmed to take the most efficient routes make food redistribution cheaper than ever. Supermarkets redistribute all edible food; what is rotten goes into methane digesters or composters. Restaurants have also gotten involved. Because driverless cars make redistribution cheaper, networks can afford to pick up smaller quantities of ingredients that go unused by restaurants. Even residential households can join redistribution networks and donate produce and other foodstuffs that they will not use.

Policy barriers have been removed thereby making it easy to join these networks. Individuals, restaurants, and supermarkets enjoy tax breaks from redistributing food. More than 95% of food that gets produced gets eaten thanks to large-scale redistribution networks run by state governments through private contractors.

Strategy #3: Food Waste to Animal Feed

Overview

Converting food waste to animal feed has been identified by the U.S. EPA and other independent studies as the most desirable food waste disposal option once surplus food is no longer of high enough quality for human consumption (USEPA, 2017a; Papargyropoulou et al., 2014). This is by no means a new or innovative practice for disposing of food waste, in fact up until "World War II, farmers and urbanités alike fed food scraps to pets, pigs, and other animals…" (Fairbanks et al., 2013, p. 526). The practice fell out of fashion in the 1980's, however, when a number of disease outbreaks around the world were linked to unsafe animal feeding practices (eg Mad Cow Disease) (Broad Lieb et al., 2016). In the wake of this public health scare a number of state and federal laws were passed to regulate the types of waste that can be fed to animals, including: The Federal Swine Health Protection Act, The Ruminant Feed Ban Rule, The Food Safety Modernization Act Preventive Controls Rules for Animals Feeding, and the FDA Regulations Regarding Adulteration & Labeling (Broad Lieb et al., 2016). Following this sharp rise in regulation of livestock feed, there was a precipitous drop in the amount of food waste being diverted to animal feed in the U.S. By 2007 "...just three percent of U.S. hog farms fed food scraps to their livestock…" (Broad Lieb et al., 2016, p. 1). As the issue of food waste has gained national attention in recent years, there has been a resurgence of interest in "using a wider array of safe, properly-treated food scraps from a range of sources—including unsold retail food and post-consumer food scraps—as animal feed" (Broad Lieb et al., 2016, p. 1). A 2015 study found that 69% of the 20.1 million megatons of food wasted at the manufacturing level is recovered as animal feed (Dou et al., 2016).

Feeding food waste to animals doesn't just make sense intuitively, it's a sound strategy from both an environmental and economic lens as well. A recent study in the UK found that disposing of food waste by feeding it to pigs has a lower environmental impact than both composting and anaerobic digestion (Salemdeeb et al., 2017). Another recent study in Europe showed that "...roughly 4.4 million acres in the European Union—currently dedicated to the production of soybeans and grain to feed pigs—could be spared by instead feeding pigs treated, recycled food scraps" (Broad Leib et al., 2016, p. 3). In addition to the potential environmental benefits of feeding food waste to animals, it also "presents the opportunity for significant cost savings in the form of reduced tipping fees that landfills and waste haulers charge for disposal of food scraps… [and] [w]aste-generating facilities typically realize savings after comparing the costs of feeding food scraps to animals to the costs of conventional waste disposal (that is, sending food scraps to landfills)" (Broad Leib et al., 2016, p. 2).

Social

Turning food waste into animal feed generates positive social outcomes by increasing participation in the food production system. As we will see in the case study, partnerships between food waste-producing institutions and local farms can create greater transparency about where food comes from and where it goes.

Environmental

Feeding food waste to animals has a lower environmental impact than both composting and anaerobic digestion, primarily because it offsets the amount of energy and resources that are consumed in growing crops for animal feed and diverts food waste from landfills were it would emit methane.

Economic

The upfront costs of switching to a food-waste to animal feed system are associated with improving refrigerated storage systems and the purchase of a pulper. Ongoing costs include increased energy demand from the refrigeration system and pulper maintenance, and pick-up fees which are negotiated with the farmer directly.

Political

There are a number of state and federal laws in place governing how food waste can be fed to animals including: The Federal Swine Health Protection Act, The Ruminant Feed Ban Rule, The Food Safety Modernization Act Preventive Controls Rules for Animals Feeding, and the FDA Regulations Regarding Adulteration & Labeling. These laws have led to a decrease in the popularity of feeding food waste to animals.

Case Study: Rutgers University

Rutgers University in New Jersey boasts one of the most successful food waste to animal feed programs in the U.S. (USEPA, 2009). The program began in the 1960's as a way to alleviate the strain on a waste disposal system that was stressed to its capacity (USEPA, 2009).
The Rutgers dining program is now the third largest dining operation in the country and serves over 3.3 million meals each year (USEPA, 2009). This translates to about 1.125 tons of pulverized food scraps per day that are diverted to feeding hogs and cattle at Pinter Farms less than 15 miles away from the campus (USEPA, 2009).

The actual process is extremely simple: Rutgers facilities staff collect food preparation and plate scraps in a large trough and feed them through a pulper which reduces the volume by 80%, before storing the pulped-food waste in large refrigerated barrels (USEPA, 2009). The barrels are then collected by Pinter Farms and hauled off to feed pigs and cattle (USEPA, 2009).

The Rutgers dining operation is well suited to a waste-to-feed partnership for a number of reasons: scale, location, and a concentrated and controlled waste stream that is easy to manage and capture (USEPA, 2009). The volume of waste generated in the Rutgers dining halls is well matched to the daily caloric needs of the Pinter Farm herds (USEPA, 2009). Pinter Farms is conveniently located just 15 miles away from the Rutgers campus, keeping transportation costs low (USEPA, 2009). Such a partnership might not be feasible in more urban areas where food scraps would need to be hauled greater distances (USEPA, 2009). Finally, the sit-down dining hall design creates a concentrated stream of food waste (generated either in the kitchen or when students bus their trays), which can be monitored by the Rutgers staff to ensure that the waste stream is free of contaminants (USEPA, 2009).

Pinter Farms charges Rutgers $30 to haul away a ton of food scraps, which is approximately half the cost of hauling away the same amount of food waste to a landfill (USEPA, 2009). In 2007, Rutgers saved an estimated $100,000 in avoided hauling fees (USEPA, 2009). In addition to the Pinter Farm's hauling fee, other expenditures in the Rutgers food waste disposal system include the one time cost of purchasing a food pulper ($45,000) and approximately $500 in annual maintenance as well as the cost of refrigerating food pulp before pickup (USEPA, 2009).

The synergy of this type of model is undeniable: Rutgers gets a cheap, local way to dispose of food scraps and Pinter Farms, in turn, is compensated for collecting a free source of feed for its hogs and cattle. Food scraps which would otherwise end up emitting methane from a landfill are recycled back into the food chain.

Looking Back from 2050

Pioneered by partnerships like the one between Rutgers University and Pinter Farms, institutions with concentrated and easily controllable food waste streams responded to increasing tipping fees by seeking out alternative disposal methods for their food waste. Especially in rural and suburban areas, local animal feedlots supplied the demand for post-consumer food waste and offered a cheap and local food disposal option. Institutions realized enough savings from decreased tipping fees that they were often able to pay off the one-time costs of improved refrigeration systems for food waste and food pulpers and eventually start saving money from the partnerships.

Driven by increasing public health concern, in 2050 there is widespread access to centralized "waste cookers" run by third party contractors. These "waste cookers" who specialize in heating food waste to the safe levels designated by the Federal Swine Health Protection Act responded to an increasing demand "safe" food waste for animal feed. Once able to contract out this costly step of the process, more smallholder farms were able to get involved with the food waste-to-animal feed market.

Strategy #4: Composting

Overview

Composting is a process of facilitating the decomposition of organic materials by combining nitrogen-rich organic wastes such as food scraps, yard trimmings, and manures in specific ratios with carbon-rich organic wastes, such as wood chips and dry leaves (USEPA, 2017d). The finished product is a dark earthy substance called humus that can be used as an amendment to improve the physical properties of soil including water and nutrient retention (United States Department of Agriculture (USDA, 2017).

Composting is a fairly simple process that can be carried out at almost any scale from a municipal level serving a large geographic area to a household's backyard setup serving a single family (Platt & Goldstein, 2014). At the municipal scale, a drawback that can be overcome is one of costs - compost facilities cost less to construct but more to operate than landfills (drawdown.org, 2017).

According to the U.S. EPA, the benefits of incorporating composting into agricultural systems are numerous, and include: reduced methane emission from landfills, carbon sequestration in soils, increased soil water retention capacity, reduced or eliminated need for chemical fertilizers, and increased crop yield (USEPA, 2017e).

According to one study, the global warming potential of composting 1 ton of food waste is 123 kg of CO2-equivalent, which is nearly 9 times less than the 1,010 kg of CO2-equivalent that would be emitted from disposing of the same amount of food waste in a landfill (emissions are reported in standardized CO2-equivalents because different greenhouse gases have different warming potentials) (Kim & Kim, 2010). However, "...while recovery of yard trimmings is well established, infrastructure for composting food scraps lags behind" (Platt & Goldstein, 2014). Composting food waste is becoming more widespread throughout the U.S., but still only accounted for 5.1% of food waste in 2014 according to the U.S. EPA (USEPA, 2017c).

Social

Composting is one of the most socially equitable solutions out there because it is a low cost solution for residential food waste and doesn't require expensive equipment. For people who live in rural and suburban areas, backyard composting is a free method for disposing of food waste and also has the added benefit of producing a free and rich soil amendment (compost) for use in home gardens. At a local scale, composting programs can increase food security and provide local jobs by improving home and community garden crop yields (Platt & Goldstein, 2014).

Environmental

Composting has about one-ninth of the global warming impact of landfilling food waste (Kim & Kim, 2010). It creates a carbon rich organic amendment that improves soil fertility and structure, and has been shown to increase crop yield (USEPA, 2017e).

Economic

Home composting is virtually free after the small upfront cost of building or purchasing a compost bin. At the municipal scale, compost facilities cost less to construct, but more to operate than landfills (drawdown.org, 2017).

Political

One potential barrier to widespread adoption of municipal composting programs is the absence of a strong federal policy promoting composting (Platt & Goldstein, 2014). Aside from a few niche grants from the Department of Agriculture and Natural Resources Conservation Service, "...there are no federal grant or loan programs for composting facilities" (Platt & Goldstein, 2014). One way to overcome this barrier is through local and state government action (Platt & Goldstein, 2014). In 2009, San Francisco, CA was the first city in the U.S. to institute a mandatory composting ordinance (USEPA, 2016c). In 2012, "Vermont became the first state to enact an all-out ban on food scraps in landfills…" with the passage of Act 148 (Flagg, 2014). Since then San Francisco and Vermont have been joined by Connecticut, Massachusetts, Rhode Island, New York City, NY, Seattle, WA, Portland, OR and California in banning the disposal of food waste in landfills (USEPA, 2016c).

Case Study: Middlebury College

Middlebury College, in Middlebury, VT, started composting food waste from its dining halls in 1993 (USEPA, 2017e). What started as a small off site operation has since grown into a school-wide program through which 90% of the food waste generated at the college is composted at a specialized facility situated adjacent to the college's golf course (USEPA, 2017e).

The composting program operates in two phases: pre-consumer and post-consumer waste recovery. At the pre-consumer level, college dining staff are specially trained to ensure that the stream of food prep scraps, and paper products involved in food delivery and preparation arrives at the centralized composting facilities free of contamination (Zannolli et al., 2012). At the post-consumer level, dining staff run plate waste and other post-consumer food residuals through a pulper to remove excess water before delivering the food pulp to a specialized hook truck that transports food waste between all of the college's three dining halls and the composting facility daily (Zannolli et al., 2012). In 2010, food waste collection was expanded to include residence halls and offices in addition to the college's three primary dining halls (Zannolli et al., 2012). At the centralized composting facility, food scraps are mixed with horse manure from a local farm and wood chips and turned in windrows until fully cured (Zannolli et al., 2012).

The entire composting operation is run by a team of five full-time staff members from the Office of Facilities Services (Zannolli et al., 2012). In 2010 the school saved $101,475 in fees associated with landfill disposal (Zannolli et al., 2012). In addition to the annual savings on tipping fees, the college produces over 500 cubic yards of compost each year (T. Parsons, personal communication, December 11, 2017). Much of this compost is used on athletic fields, landscaping features, and in the college greenhouse as a valuable soil amendment (Zannolli et al., 2012; Middlebury College, 2017), representing an additional saving of $25 per cubic yard (T. Parsons, personal communication, December 11, 2017).

Looking Back From 2050

Though the early success of the Middlebury composting program was promising to the future of large scale composting operations, institutions like colleges only contributed 8% of the food waste generated in the U.S. in 2014 (USEPA, 2016c). Composting programs that had the biggest impact on diverting 100% of biological nutrients from landfills by 2050 came from the residential and restaurant sectors, which contributed 56% and 26% of food waste in 2014 respectively (USEPA, 2016c).

Only 2.4% of U.S. households were served by residential food collection and compost programs in 2014 (USEPA, 2016b). According to Diffusion of Innovation Theory, this strategy was still in the “Innovators” stage in 2014, meaning that <2.5% of the population had adopted the practice, and those that had were likely venturesome and very willing to take risks and try new things (LaMorte, 2016). Driven by increasing concern over the contributions of landfill methane emissions to global warming, an increasing number of local and state governments passed mandatory composting ordinances modelled after the San Francisco Mandatory Composting and Recycling Ordinance (2009) and Vermont Act 148 (2012). As increasingly strict regulations of food scrap disposal in landfills began to phase in, there was a sharp rise in the incidence of backyard composting and municipal food collection programs.

In 2050, composting is the primary biological waste disposal method for the residential sector, both through backyard composting for those living in rural and suburban areas, and through municipal-level food collection programs, which bring food waste from restaurants and residents in urban areas to centralized composting facilities in every city.

Strategy #5: Anaerobic Digestion

Overview

Like composting, anaerobic digestion is a process of facilitating the breakdown of organic materials into their component parts, however, unlike composting, anaerobic digestion occurs in the absence of oxygen (USEPA, 2016e). Anaerobic digesters are specialized tanks that maintain optimal conditions for bacteria to break down organic material, and can range in size from a refrigerator to a small building (American Biogas Council (ABC), 2017). Any organic material can be broken down through anaerobic digestion, but food waste, yard clippings, animal manure and sewage are some of the most common and well-suited feedstock for anaerobic digesters (ABC, 2017).

The process of anaerobic digestion generates heat and two valuable by-products: biogas and a solid fraction that can be used in agriculture as a fertilizer (USEPA, 2017f). Biogas is composed primarily of methane, which is 20 times more potent than CO2 as a greenhouse gas (ABC, 2017). When organic waste breaks down in landfills much of this methane leaks into the atmosphere where it contributes to global climate change. Anaerobic digesters capture this gas in a form that can be used as a renewable alternative to fossil fuels (ABC, 2017).

There are currently more than 1,500 anaerobic digesters operating in the U.S. which are spread primarily across farms and municipal wastewater treatment plants (ABC, 2017). By comparison, Europe currently has over 10,000 operational anaerobic digesters. The American Biogas Council (ABC) has noted that there is room for significant expansion of this strategy in the U.S. and has already identified more than 11,000 sites that could support and make use of an anaerobic digester (ABC, 2017). The ABC further asserts that “[i]f fully realized, these biogas systems could produce enough energy to power 3.5 million American homes and reduce emissions equivalent to removing 800,000 to 11 million passenger vehicles from the road” (ABC, 2017).

Social

According to the U.S. EPA (2015), “[anaerobic digestions] projects support sustainable, resilient, and livable communities by reducing fossil fuel consumption; producing a local source of renewable heat, electricity and/or fuel; lessening odors; and strengthening the local economy by reducing energy costs and generating revenue” (p. 6). Anaerobic digestion has significant public health benefits by diverting food waste from landfills where it emits noxious gases such as methane (USEPA, 2015). Processing food waste for anaerobic digestion is more labor intensive than processing sewage, thereby creating the need for jobs where previously there was none (Day, 2012).

Environmental

Anaerobic digestion captures methane that is emitted from the decomposition of organic materials and captures it in the form of biogas that can be used as a clean energy alternative to fossil fuels (ABC 2017; USEPA 2017i). The solid byproduct of this process can be used like compost as an agricultural amendment to increase soil health and improve crop yields (USEPA, 2017i).

Economic

As is shown in the following case study, anaerobic digestion of food waste can generate enough biogas to power the waste treatment plants that they are connected to and even enough to sell energy back to the grid (Day, 2012).

Political

The U.S. Environmental Protection Agency recognizes anaerobic digestion as a viable strategy for diverting food waste from landfills (USEPA, 2015). As is shown in the East Bay Municipal District case study in the following section, local zero waste goals and mandates can drive adoption of anaerobic digestion as a biological nutrient diversion strategy (East Bay Municipal Utility District (EBMUD), 2017a).

Case Study: East Bay Municipal Utility District (EBMUD) in Oakland, CA

For the past 7 years, East Bay Municipal Utility District (EBMUD) in Oakland, CA has been piloting a food scraps to biogas program pursuant of San Francisco's zero waste goals and mandates, and now plans to scale the program up in the coming years (EBMUD, 2017a).

By one estimate, EBMUD "...could be selling twice as much electricity as it uses…" by 2020 (Day, 2012). The pilot program began in 2002 and in just 10 years of operation EBMUD has become the "...the first water or wastewater utility in the nation to sell excess electricity produced solely from waste material back to the grid" (Day, 2012). The process of generating electricity from biogas is so efficient that in 2012 EBMUD was emitting about a third of the NOX levels it was permitted for (Day, 2012).

The program has been a huge economic success. In 2012 EBMUD was generating $500,000 in revenue from selling excess electricity back to the grid and this number has been projected to grow as the district's food waste diversion program continues to expand (Day, 2012). Additionally, EBMUD makes $30-65 in tipping fees per ton of food waste delivered to the wastewater utility and saved about $2.5 million dollars a year in electricity bills in 2014 (Day, 2012). Wastes accepted under the R2 program include "...chicken blood from a poultry processor, waste from wineries and dairies, septage from septic tanks, pumpings from portable restrooms, animal processing and rendering waste, water and wastewater sludge, and other commercial and industrial process wastes" (Day, 2012). With the newly diversified waste stream have come a number of problems including contamination by plastic silverware, feathers, grape stems and a host of other factors that can jam up the machines, but innovations in the way the waste stream is processed prior to entering the anaerobic digestion tanks has improved contaminant removal greatly (**Fig. 7)** (Day, 2012).

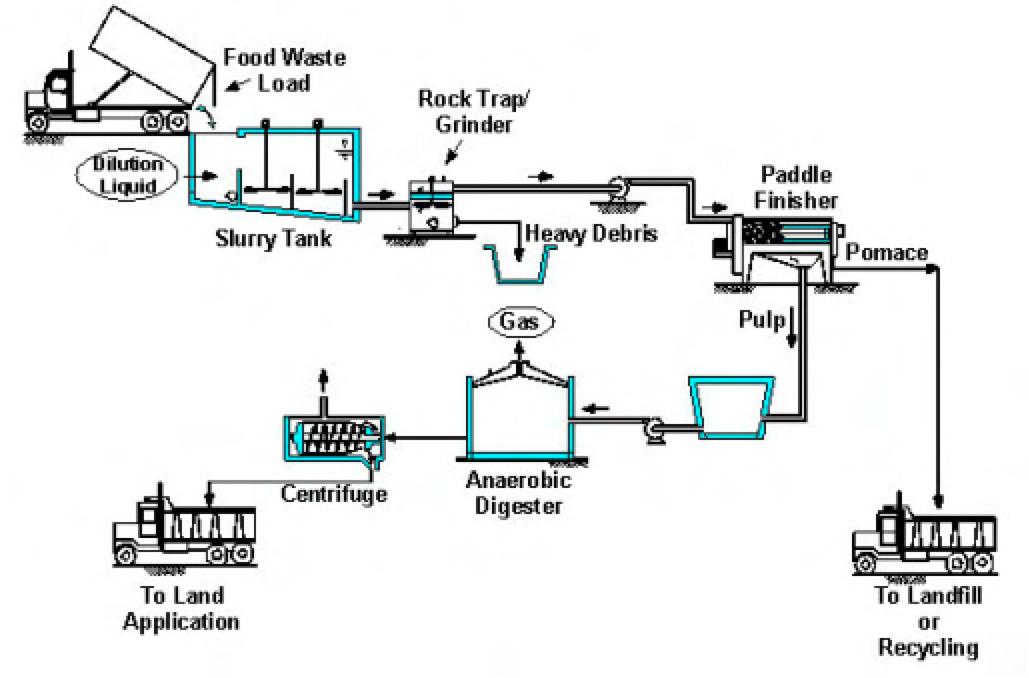


Figure 7. East Bay Municipal Utility District food waste treatment process (Gray et al., 2008).

Looking Back from 2050

In 2050, every major city in the U.S. has an anaerobic digestion facility attached to its wastewater treatment plant. Driven by increasing concern about climate change, cities and states all over the U.S. have adopted zero waste goals and mandates similar to San Francisco's trail-blazing initiative. Anaerobic digestion facilities are modeled after EBMUD's (**Fig. 6**) in which existing infrastructure is optimized for co-digestion of food scraps and municipal sewage waste. As predicted by the ABC, the 11,000 additional anaerobic digestion facilities built in the U.S. since 2017 are producing enough biogas to power millions of homes (ABC, 2017).

SECTION 2: Technical Nutrients

Introduction

Technical nutrients is a term developed by William McDonough and Michael Braungart in their book *The Upcycle*. They define technical nutrients as: "[m]etals, plastics, and other materials not continuously created by the biosphere" (McDonough & Braungart, PAGE NUMBER 2013).

This means that there is a finite supply of these resources on a human timescale, and therefore, discarding them means future generations will have a smaller abundance of them than we do today.

The U.S. had a nationwide diversion rate of roughly 35% in 2014 (USEPA, 2017j). This means that for every 100 pounds of waste generated in the U.S., 65 pounds ended up in landfills. New York, the largest metropolitan area in the U.S., had a diversion rate of only 15% in 2010, far lower than the national average (Dover, 2013). San Francisco on the other hand successfully increased its diversion rate to 80% by 2012 and is continuing to improve (USEPA, 2013). This demonstrates that well-implemented strategies can have a significant impact on the amount of waste that is disposed of from one city to the next.

In this section, we focus on alternative strategies to dumping technical nutrients into landfills at the end of a product's life. We believe that these strategies are scalable on a national level. These strategies will help turn materials from waste into food for future products that will enable a closed-loop economy (McDonough & Braungart, PAGE NUMBER, 2013)

Strategy #6: Virgin Raw Material Tax

Overview

It is interesting to think that companies can profit from the extraction of natural resources from a globally finite stock at a rate that will not allow future generations to have the same standards of living, without contributing any of their gains to societal progress writ large. It is even more remarkable that this occurs simultaneously with many people throwing away the same material that is being extracted, into landfills at the end of the product's intended use, thus perpetuating a cradle to grave cycle.

One major hurdle the recycling industry has faced has been low demand for recycled materials (*Harvard business review on business and the environment*, 2000). This has been in part due to producer perceptions about quality as a substitute for virgin raw materials and partly to the availability of low cost, virgin alternatives (Miller, 2016).

Let us first examine the higher prices. It is not surprising that only several decades after a large-scale recycling infrastructure has been in place, not all recycled raw materials are cost competitive with their virgin peers. This largely because the technology for extracting and processing the material has been improved decade by decade for centuries; whereas, the infrastructure for recycled material collection and the technology for recycled material recovery are relatively new (*Harvard business review on business and the environment*, 2000). Quality of recycled raw materials has also been steadily improving over time as technology and processes improve (Miller, 2016).

The relatively low prices of virgin raw materials do not factor in the numerous external costs that go into producing them – specifically, the costs they impose on future generations from depleting natural resource stocks (World Scenario Series, 2014). Additionally, recycled raw materials generally use less energy to produce and thus do not generate many of the issues associated with raw material extraction such as biodiversity loss, groundwater contamination, noise pollution, and habitat destruction (Söderholm, 2011).

In this strategy, we propose a corrective tax be placed on the extraction of virgin raw materials to help incorporate the external costs including the cost that using them today will inflict on future generations. The revenue generated from the virgin raw material tax would help fund a subsidy program to temporarily lower the price of recycled materials so that the technology can improve to the point where it is cost competitive with raw material extraction. This relative price decrease would increase the demand for recycled raw materials and help drive the movement to an economy that no longer relies on constant resource extraction at an unsustainable rate (Söderholm, 2011).

Social

This strategy has few direct social benefits, as it is directly targeted towards business; however, one does not need to go far from the source to understand the positive social impacts. For one, lowering the volume of material that is extracted from the earth results in needing fewer mines. As a result, the tax allows more land to go untouched and natural stocks to go undisturbed by industry.

In the long term, this strategy has significant social benefits in the form of intertemporal equality of access to resources. At the current rate of extraction, and without the rapid substitution of recycled raw materials, future generations will not have the same access to cheap and abundant materials that we do today. This will create economic hardships for them that they face only because current generations unnecessarily consumed more than their fair share of the finite resource supply and carelessly discarded the materials at the end of one use.

Environmental

This tax has a two-fold benefit for the environment. For one, it will decrease the quantity of resource extraction points through a decrease in demand for virgin raw materials. As mentioned earlier, these sites are known to contribute to groundwater contamination, biodiversity loss, noise pollution, and habitat destruction. Additionally, recycled materials, on average, require less energy to produce than virgin raw materials, so the tax would help reduce the overall carbon footprint of product consumption.

Economic

This is a tax that would anger many industries and would be viewed as an unfair and unnecessary burden to be borne by industry. For an economically efficient tax to be placed on the virgin raw materials, an extensive study would need to be performed to quantify the social and environmental costs of depleting the current reserves with environmentally damaging methods. The tax would be beneficial in the long run economically, as it will help incorporate the price that extracting resources today has on future generations into materials. As a result, future generations will have access to a closed-loop economy in which they do not have resource insecurity.

Political

For the political environment to get behind such a tax, the "polluter pays" principle needs to become widely accepted. Additionally, there needs to be a bipartisan agreement on how to place monetary values on environmental and social issues ranging from the value of biodiversity loss to how much we value resource insecurity of future generations.

Case Study: Denmark

Denmark implemented a tax on raw material extraction beginning in 1977 (Söderholm, 2011). Denmark also implemented a waste tax in 1987 that began by increasing the tipping price by $6. The tax rates have slowly increased since. The tipping fee tax is now $47 per ton, and the raw materials tax has increased 25 percent. The intention of these two acts was to lower the rate of resource extraction and replace the demand with recycled material.

Between 1989 and 2009, the total raw material extracted that was covered under the tax declined slightly. The increase in price resulting from the tax found its way through to the consumers, increasing the price of the final good.

Although it cannot be said that the tax directly caused this, Denmark had remarkable success in its diversion of material from construction and demolition projects from 1985 to 2004. In 1985, 12 percent of material of these materials was recycled and 82 percent went to landfills. By 2004, 94 percent of the material was recycled.

Looking Back From 2050

Virgin raw materials taxes are widespread and widely accepted. There are fewer mines today, but most people attribute this to the efficiency and relative cheapness of recycled raw materials. What they don't realize is that a large driver of this was the Virgin Raw Material tax passed in 2032. The tax was motivated by the uPollute, uPay movement of the 2020s. Once a comprehensive examination of the true price of virgin raw materials had been conducted by the EPA, the act was passed. The tax differed depending on the material-specific study and was phased in gradually over a ten-year period to allow industry to adapt. This period lined up with the adoption of product stewardship laws, and between the two new regulations, there was a widespread shift in the prevalence of recycling products that include multiple technical nutrients.

Today, materials are still being extracted from the earth, but only at a rate to meet the increasing material demand of the growing population.

Strategy #7: Product Stewardship

Overview

One major driver of technical waste in the current state of consumer culture is that companies manufacture products to be used once – sometimes even artificially limiting the length of time a single product can be used (Planned Obsolescence, 2007). The cost of disposing of a product that has broken, become obsolete, or is no longer of any use typically falls on the consumer. Consumers often face other issues in properly disposing of a product due to access or misinformation issues. Additionally, products are often made without the disposal in mind and cannot not be disassembled even if brought to the correct location for safe disposal.

As a result, products that contain valuable, finite materials, are discarded and end up in landfills, where they lose any future potential of contributing to economic growth. This drives the predominantly resource-linear economy: one in which virgin raw materials are put into a product, used once over the course of the product's lifecycle, and then discarded never to be used again.

In order to eliminate waste by 2050, it is imperative that we wean ourselves from this mindset and create a new norm in which producers think of the entire lifecycle of the products they put on the market. This strategy suggests that through government-mandated product stewardship, companies will outsource product stewardship responsibilities to third party businesses that specialize in the collection, dismantling, treatment, and recovery of the materials in products and their packaging.

This will change the current system, in which producers defer the costs of using wasteful, excessive, and unnecessary materials in products on future generations. It will require companies to optimize the amount of material they use for the purposes of the product, while also considering, and formulating a plan for how the materials will be reused and reclaimed once the product is no longer functioning or needed.

This will be a major catalyst for a closed-loop economy – one in which the inputs into the economy match the materials in products that are no longer needed. Companies will no longer be able to disregard the life of their product after they receive the revenue from it. They will need to make a comprehensive plan for how the consumer can easily get the product into the hands of a company they have already paid to handle the material reclamation (*New York Product Stewardship Council*).

Social

As this strategy suggests, product stewardship requires both regulations that require companies to adhere to expectations about end of life product management, as well as a change in mindset. The regulations that oblige producers to provide comprehensive plans and pay for end of life management are important politically, but the change in mindset is what drives this strategy in the long run. Product stewardship's largest contribution to society is that it will drive a change in the way we think about the materials in our products. With a product stewardship approach, material is thought of less as something that can be bought, owned, and sold, but rather as something that can be borrowed indefinitely – for however long one has a use for it – before allowing it to be put back into the cycle.

Environmental

One of the most important aspects of product stewardship is that it that it fosters a concern surrounding an environmental ethic for product designers and producers. Product stewardship acts as a way to divert material away from landfills at the end of its products life cycle, which in turn generates a higher supply of recycled materials that act as a substitute for those that previously may have been extracted from a finite stock.

Economic

Product stewardship requires that there be a way for producers to take responsibility for the end of life recycling of the material in their product. On a large scale, the best approach to this is one in which this function can be outsourced to companies that specialize directly in materials recovery and recycling. As it relates to the scope of this strategy specifically, the regulations would need to generate industry demand for third-party, private companies for industries to outsource their product stewardship responsibilities to. The producers and designers of the products would send a disassembly and material recovery plan to one of these firms with whom they have contracted. The producer would then put an indicator on the product to show which material recovery company should be sent the product once it's first life cycle is over. The material recovery company would then charge the producer a fee in addition to owning the newly recycled raw materials. For this strategy to work, outsourcing needs to be the industry response to product stewardship regulations, sufficient economies of scale need to be met for the material recovery firms to be profitable, and there need to be enough material recovery firms that no monopolistic economic conditions form.

Political

One difficult aspect of product stewardship implementation is that it requires a change in mindset surrounding a product's externalities. This change in mindset must begin before a product stewardship law would even be considered at the national level. For regulations to go into effect, politicians, businesses, and consumers must first understand that the regulations are not designed as a burden on industry, but rather are there to correct for a market inefficiency that we have been conditioned to overlook.

Case Study: Germany

In the 1990s, Germany enacted a product stewardship law that made companies financially responsible for the packaging associated with their products. Additionally, the companies needed to provide a way for their customers to dispose of the packaging. In response to this act, companies came together to form a new company that they could outsource their product stewardship responsibilities to for a fee (*Harvard business review on business and the environment*, 2000).

The company, Der Grüne Punkt – Duales System Deutschland GmbH (DSD) has been very successful and is still around today. By 2007, DSD had helped Germany reduce the per-capita landfill contributions to 3 kilograms per year while also eliminating any municipal waste incineration (Doru & Giușcă, 2010). Companies pay DSD to put their certification, called Green Dot, on the packaging. DSD then assumes all the responsibilities of collecting, sorting, and recovering the material used in the packaging.

The Duales system is one through which consumers separate their trash and recyclable packaging materials. The collection of the recyclables is financed by the Green Dot program and carried out by DSD.

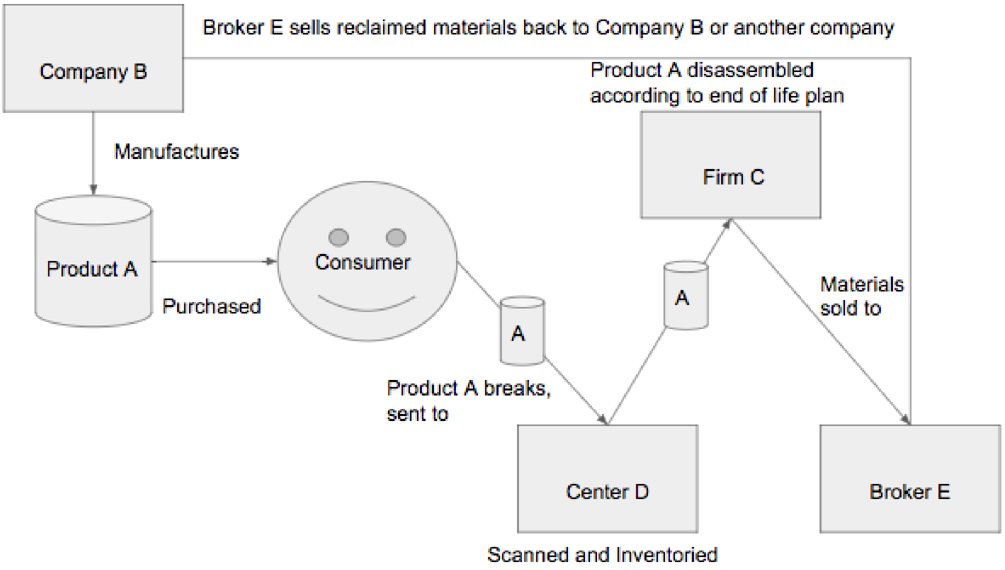
This law was so successful that almost immediately retailers began to stop carrying products that didn't have the Green Dot logo on them. Additionally, companies started using less and less material in their packing so they would not have to pay as much to DSD. DSD has also been quite successful as a company and is estimated to be worth between 100 - 250 million euros (Industry sources: Remondis plans DSD takeover, 2017).

This is not a perfect example, however. There have been issues with generating competition, as DSD has had rights over the Green Dot logo, which has acted as a huge barrier to entry for new companies. This has most likely impacted both the price DSD can charge for its services and allowed to DSD to strive less for efficiency measures than they may have otherwise (Birkenstock, 2013).

Additionally, this law was enacted in the early 1990s and still only extends to packaging. This does not go to the same extent as the strategy we propose, which would cover everything from product packaging to the products themselves.

Looking Back From 2050

All products now contain microscopic, scannable chips in them. Let's follow Product A. Product A was manufactured by Company B, who outsources its product stewardship responsibilities to Firm C. The chip in Product A identifies the relationship between Company B and Firm C. Once Product A becomes obsolete, broken, or is no longer desired, it is brought to the local product reclamation center, Center D. This center scans Product A and inventories it along with all other products they have recently received that are destined for Firm C. Once the Center D has collected a sufficient amount of products for a company, product A is sent to Firm C. Firm C scans the chip and the end of life management plan that Company B sent them gives them an efficient method to use to reclaim the individual materials in Product A. Firm C then charges Company B for its services, and also sells the recovered material to Broker E.


Broker E sells reclaimed materials back to Company B or another company
Company B
Product A disassembled according to end of life plan
Manufactures
Firm C
Product A
Consumer
Purchased
A
A
Materials sold to
Product A breaks, sent to
Center D
Broker E
Scanned and Inventoried

This process is no more difficult for the consumer than it was for them to discard a product in the early 2000s. It took a long time for the system to run efficiently and profitably without any government subsidies, but is no longer noticed as anything other than the norm by the consumer. The initial product stewardship law was passed in 2025 and required companies with more than $100 million in annual revenue that manufacture products to create a plan and a way through, which their customers could dispose of their products in compliance with the law. This plan was to be phased in over the next five years. Several product stewardship outsourcing businesses were quickly started in Silicon Valley that got traction in the venture capital community. Once 2030 came around, the law went into effect. That same year, expectations were set for all companies with over $1 million in revenue. They too had five years to generate product stewardship plans and find a firm to outsource the responsibility to before they were expected to be in full compliance. By 2045, all producers were expected to comply and hence, the product stewardship laws were fully in effect.

Strategy #8: Single Stream Recycling

Overview

Single stream recycling is a process that allows households to put mixed paper, cardboard, newspapers, tin and aluminum, scrap metal, glass bottles and jars, plastic bottles, jugs and containers, and milk cartons all in the same bin to then be separated (Northeast Michigan Council of Government, 2016). Many cities are choosing to switch to single-stream recycling because of cost reductions and the possibility of higher diversion from landfills (HDR, 2012). There is contention over whether single stream recycling is that much better than dual recycling systems and it comes down to what current waste management practice is already in place and whether single stream will lower costs and increase diversion. A study conducted by R.W. Beck in 2005 showed that access to single stream systems in America has increased from 11% in 2000 to 27% in 2005 (HDR, 2012).

Overall studies show that the process of collection is more productive and its associated costs are reduced for single stream recycling. Key factors that contribute to this reduction in collection costs are the option of machine- operated collection, larger wheeled bins, and removal of curbside sorting (HDR, 2012).

In terms of processing the materials once they leave the curb, the costs associated with processing are higher than those of dual stream recycling. There are higher upfront costs associated with running the facility and paying for labor (HDR, 2012) Another issue cited by recovery facilities is that the materials from single stream systems are lower quality and contaminated. Dealing with this issue requires the public to better understand what items go into single stream recycling bins and ensuring sorting facilities are run at a high standard (HDR, 2012).

Many studies cited that participation, educational outreach, and accessibility play a role in the success of a single stream-recycling program. The cost and diversion benefits will most likely not be found if the public is not educated on how to use single stream recycling.

Transitioning to single stream recycling is a viable option for diverting more waste from landfills, lowering long-term collection costs, and improving public participation. The benefits of single stream recycling must be looked at on a case-by-case basis but with substantial environmental education and outreach we are recommending cities move towards single stream recycling. It is important to note that single stream recycling is a step in the right direction but ultimately source reduction is imperative.

Social

The main social benefit of single stream recycling is that it will increase public participation because there is greater ease to the system. Successful implementation of single stream recycling requires substantial recycling education.

Environmental

Single stream recycling benefits the environment because it increases diversion of waste from landfills. This is important because a significant amount of waste ends up in large landfills.

When waste decomposes in landfills it releases greenhouse gases such as methane, which contributes to global warming.

Economic

Single stream recycling reduces collection costs due to a more streamlined collection process using less bins and manual labor. Initially switching to single stream recycling may contribute to higher upfront costs for collection, establishment, and operation of a materials recovery facility. These costs could be funded through a pay as you throw fee. For example residents have to pay a small fee each time they put out the trash. States may also require residents to pay for recycling and waste programs through their property taxes.

Political

For successful implementation of a single stream recycling system there must be strong municipal leadership and support. The municipal government must create a program that incentivizes the public through monetary rewards and educational opportunities. The municipal government is motivated to lead their communities because they are under the jurisdiction of the federal government and if they are looking for additional funding for programs they must that they are able to implement a successful program.

Case Study: Grand Rapids, Michigan

Grand Rapids is a city that is well known for its successful recycling initiatives. Grand Rapids has a population of 193,792 people and is growing quickly (Northeast Michigan Council of Government, 2016). As mentioned above it is critical when implementing a new recycling system such as single stream recycling to also have recycling education. Grand Rapids has a website for recycling and solid waste initiatives that clearly outline the city's goals and how the public can best participate. In order to incentivize the public to participate in the program, the city offers myGRcity points, which gives residents points for recycling and these points can then be used at local businesses. Residents also have access to the Kent County's Recycling and Education Center a materials recovery facility (MRF), opened in 2010. Single stream-recycling programs are dependent upon a well-run MRF. The public is allowed to come into the facility and see the materials being sorted.

A key element of a successful recycling program is providing accessibility to the public. Therefore, Grand Rapids offers residents bi-weekly curbside collection. In 2010 the city started utilizing wheeled carts, which are easier to use than heavy bins. Garbage and yard waste are paid for through the Pay as You Throw fees requiring residents to pay a fee between $2 and $6 each time they put out trash. To track residents disposal, the city partnered with Cascade Cart Solutions to put Radio-Frequency Identification (RFID) tags on garbage bins and recycling bins. The collection crews scan the RFID tags and charge the resident based on amount of garbage and how many times it is put out. These tags also allow the city to track how much garbage their residents are putting out for collection (Northeast Michigan Council of Government, 2016).

Recycling is funded entirely through a waste property tax. (Northeast Michigan Council of Government, 2016). The curbside collection program collects (paper, cardboard and paperboard, glass, plastic containers #1-#7, aluminum and tin cans, plastic grocery bags, telephone books, and yard waste). The county also has three recycling centers where residents can drop off recyclables for free and there are four hazardous waste facilities where residents can drop off their waste. Businesses can participate in the program if they have access to a street. Multi-family residents do not have access to the program and have to coordinate with a waste hauler to provide services for resident families (Northeast Michigan Council of Government, 2016).

Grand Rapids attributes its success to strong municipal leadership from The Director of the Department of Public Services and the Office of Energy Sustainability, and the creation of a program that is accessible to the public and incentivizes participation through monetary means and educational opportunities. Participation has increased by ~ 80% since 2010 and ~45,000 households are participating (Northeast Michigan Council of Government, 2016).

Looking Back From 2050

Every state in the U.S. has thoroughly reviewed their recycling program and has implemented single stream recycling along with a public outreach program to ensure public cooperation. This was made possible through each states commitment to empowering local leadership to develop a recycling program that was transparent, accessible, and cost-effective. The programs were successfully implemented because through educational programs the public understood the value of the recycling program and how to participate. The states developed cost structures that incentivized the public to participate in the program and to reduce waste disposal. The states used a RFID tagging system to track how their residents were doing with the program and continued to expand on outreach efforts. Policy makers were motivated to implement successful programs because of the efficiency of a single stream recycling system, the prospect of increased public participation, and reduced collection costs.

Up-and-Coming: Strategy #9: Materials Bank

Overview

This strategy looks forward to how the recycled materials market responds to the other products' stewardship strategies. It is a thought experiment to examine how new market forces would affect the private recycled material sector. This strategy looks at a new type of company, a materials bank, that serves the functions at different points within the recycling process so that it can capitalize on economies of scale, lower transaction costs, lower overhead costs, and increased efficiency from smart demand response networks. Unlike the previous seven strategies, the materials bank is still in the conceptual phase and no prototype exists today, hence there is no case study for this section.

A materials bank, as we imagine it, is a vertically-integrated, value-added, for-profit firm that operates in the recycling industry as a re-distributor/broker. The firm receives recycled material in its post-consumer state from various waste-collection companies. Materials banks also act as a third party for companies to outsource product stewardship responsibilities to. They have models that can recognize a product, assess the product stewardship plan, and then disassemble the materials in the product and relocate the separated raw materials to their correct locations.

Materials banks store raw recycled materials in warehouses to have on demand for their customers. Materials banks act as a broker for manufacturing companies to supply them with dependable, recycled raw materials. Materials banks capitalize on economies of scale, and overhead reductions that come along with the vertical integration. They much better define systems and networks within the firm that allow them to efficiently disassemble, sort, treat, and move the materials to the correct locations.

Because there are many material banks, they would stabilize the prices for raw materials and make them publicly available. Additionally, materials banks would be good for producers and manufacturers because they would take out some of the systematic risk in virgin raw materials that come from uncertainties surrounding resource scarcity and natural disasters (Shulman, Corr, & Ibanez, 2010).

Social

The social benefits of materials banks are indirect, but they would exist. Materials banks would create jobs and contribute to the closed-loop economy that will ensure a consistent supply of materials in the long run.

Environmental

Materials banks will be crucial stage in the closed-loop economy. By reducing the demand for raw materials in this “re-use” method the environmental benefits are many - and include all those associated with a closed-loop economy, including the negative impacts of virgin raw material extraction and processing (toxic chemical runoff, impacts of mining, etc.) This is an important stage in the closed-loop economy, which is a prerequisite to reaching a point in which we produce zero solid waste and minimal new material is being added into products.

Economic

Materials banks, as described in this strategy, are a culmination of the response to a country-wide adoption of the other three technical nutrient strategies. Once these strategies are widely practiced and the majority of technical nutrients are diverted, materials banks will form in order to capitalize on economies of scale, demand response, and efficient product disassembly.

Political

Materials banks require all the same political conditions to be met that product stewardship laws, a virgin raw materials tax, and single stream recycling did, as it is the culmination of the interaction between the three strategies.

Looking Back From 2050

Materials banks make up a large industry. They are a vital part of the consumer economy and a driver of the closed loop economy. They were formed in the late 2030s, when materials recovery facilities began to merge with outsourced product stewardship firms. As the diversion rate increased in the late 2030s, the timing of their supply was inconsistent. As a result, there was temporarily dramatic price volatility for recycled raw materials. Congress then passed an act that required materials banks to always keep a certain supply of recycled raw materials in supply. This helped stabilize the prices and guaranteed manufacturers a dependable supply and price of raw materials.

Strategy #10: Toxic Waste Prevention Program

Overview

Although we did not conduct an extensive amount of research on toxic waste, our preliminary research suggests that source reduction is imperative. Many states in U.S. have toxic waste treatment plans and household plans for what to do with toxic waste. It is important to have these plans in place so that toxic waste is properly handled and gets to the right final destination as to not pollute our waters or negatively affect our health. We chose to look at the larger picture and suggest that in order to get to zero waste by 2050 it is imperative to look at source reduction: *how can we reduce toxic waste at the source so these treatment plans are not necessary?* The U.S. EPA calls this “Pollution Prevention” and notes that this strategy reduces costs associated with waste management and cleanup of toxic waste as well as protects from environmental disasters and negative health implications. In 1990, congress passed the Pollution Prevent Act, which said "the Environmental Protection Agency must establish a source reduction program which collects and disseminates information, provides financial assistance to States, and implements the other activities....(Pollution Prevention, 2017)" Congress passed this act because it was found that the U.S. was producing millions of tons of hazardous waste and spending billions of dollars a year managing the waste. They pointed out that many industries do not look towards prevention plans because they think that the treatment plans are taking care of the waste. It is important to address reduction at the source in order to create a top down effect and ultimately have less hazardous waste to manage (Pollution Prevention, 2017).

Congress appointed the U.S. EPA to implement the national pollution prevention policy, which says that pollution must be reduced or eliminated at its source and pollution that cannot be eliminated must be handled in a safe way. The U.S. EPA mandates that businesses report on their progress (Pollution Prevention, 2017).

Social

Reducing toxic waste is imperative because it is detrimental to the environment and to human health. Toxic waste also disproportionately affects minorities and individuals in low-income communities. Therefore, it is critical that toxic waste prevention programs are implemented in states across the U.S.

Environmental

Toxic waste is dangerous for human health, animals, and the environment. If toxic waste is not handled properly it can accumulate over time and seep into wells or drinking sources.

Economic

Financially it is expensive to manage hazardous waste and therefore reducing toxic waste at the source through pollution prevention programs is imperative. Funding for hazardous waste programs may come from a variety of avenues. In Oregon one of the funding sources is The Annual Compliance Determination Fee which requires companies to pay if they are managing hazardous waste. Funds also come from tipping fees, costs for hazardous waste clean-up, U.S. EPA grant money, and state funds (State of Oregon, 2017).

Political

There is controversy in politics surrounding hazardous waste as the public says that the waste regulations from the federal and state government are too lenient while some corporations say the regulations are too stringent (Toxic Waste, 2009). In order for successful pollution prevention programs to be put in place, states must implement their own acts to strengthen the EPA’s rules, such as Oregon's Toxic Use and Hazardous Waste Reduction Act of 1989. This type of state legislation act would require companies to develop their own plans to reduce toxic waste.

Case Study: Oregon's Toxic Use and Hazardous Waste Reduction Act of 1989

Oregon was one of the first states to mandate pollution prevention with its Toxic Use and Hazardous Waste Reduction ACT of 1989. The act requires that businesses that produce any amount of toxic waste including those using the Federal Toxics Release Inventory comply by doing the following:

1. Develop a Reduction Plan or Environmental Management System
2. Submit a Notice of Plan Completion or EMS Completion Electronically
3. Submit two Implementation summaries electronically
4. Update Reduction Plan or EMS when changes occur and keep it on site.

Success story under Oregon's Toxic Use and Hazardous Waste Reduction Act of 1989

The Boeing of Portland company was using a toxic substance called trichloethane for preparing and cleaning the surface of materials that would be manufactured into airplane parts. Since the implementation of Oregon’s Toxic Use and Hazardous Waste Reduction Act of 1989, Boeing of Portland has thoroughly reviewed their practices and developed a reduction plan. Boeing removed the Detrex open top trichloroethane vapor degreaser and was able to remove any trichloroethane from the production process. The company is now investigating n-propyl bromide as an alternative. Since doing so, the company has reduced 12,000 pounds of this chemical. A second substance that Boeing looked into because of the law was Petroleum Naptha Solvent Cleaning used for rinsing materials. Petroleum Naptha solvent can contain the carcinogen benzene which has negative health ramifications (New Jersey Department of Health and Senior Services, 2007). The company switched to a different washer that left oil as a final product instead of Petroleum Naptha. Since finding an alternative, the company has reduced 40,000 pounds of the solvent. In order to comply with the act Boeing reviewed each of the toxic chemicals they use and developed a management plan that worked towards source reduction (First Implementation Report, 2006).

Looking Back From 2050

Every state in U.S. has created a Department of Environmental Quality that specifically focuses on regulation of hazardous waste and enforces legislation. All states have implemented waste reduction acts through the Department of Environment Quality that require private and public sector companies to develop long-term reduction plans with the aim of reducing toxic waste at the source. The Environmental Protection Agency oversees the successful implementation of these acts and supports the legislation. The Department of Environmental Quality has implemented hazardous waste trainings to help residents and companies understand how to reduce and manage toxic waste. The Department of Environmental Quality has been a key leader as they are a bridge between the U.S. EPA and the corporations. These programs have been funded through a series of fees given to companies managing toxic waste, tipping fees, clean-up costs, grant money from the U.S. EPA and state funding.

Section 3: Education

Introduction

Successful implementation of waste reduction programs requires public participation and education. In order to increase public participation humans must be motivated to take action which requires caring about the environment. Educational strategies such as labeling, environmental curriculum, and public outreach are critical to provide all individuals with the opportunity to make environmentally sound decisions by creating access and encouraging sustainable behavior change.

Strategy #11: Behavior Change

Overview

To change buying habits, we must invest in consumer education to create access to the information needed to make an educated decision. One proven way to accomplish this is through product labeling practices. Just as nutrition facts have helped consumers make educated decisions in terms of health, environmentally-oriented labels on products can raise awareness to educate consumers on the environmental effects of a product. **Figure 8** shows that reducing CO2 emissions reduces waste. When consumers indicate to a company that they prefer products with lower emissions, companies will be forced to manufacture recycled products thus leading to less introduction of new virgin materials and less waste.

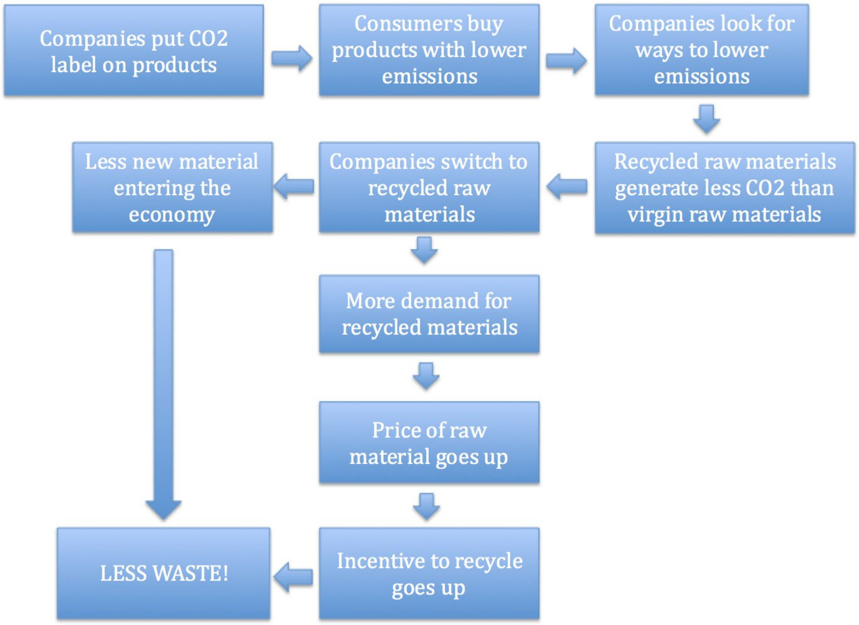
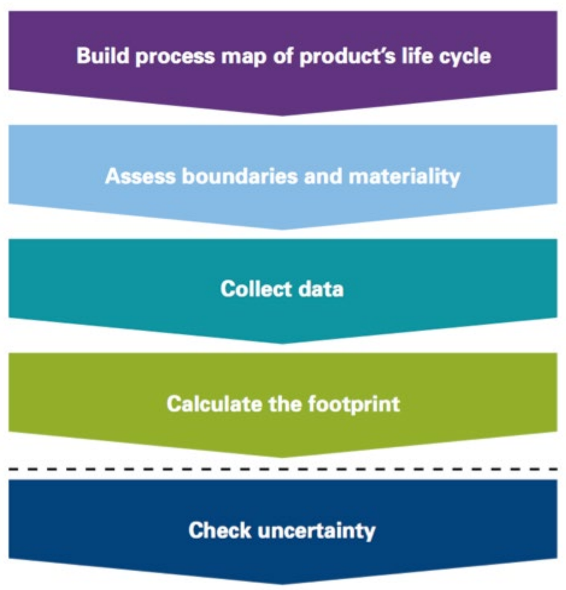

Companies put CO2 label on products
Consumers buy products with lower emissions
Companies look for ways to lower emissions
Recycled raw materials generate less CO2 than virgin raw materials
Companies switch to recycled raw materials
Less new material entering the economy
More demand for recycled materials
Price of raw material goes up
Incentive to recycle goes up
LESS WASTE!

Figure 8. Flow chart explaining the relationship between CO2 and waste Labeling

Carbon Dioxide (CO2) labeling is a method to convey to the end user the amount of carbon emissions required to produce a product. While CO2 and waste do not have a clear, direct relationship, reducing one generally reduces the other. It has been shown that adding CO2 labels onto products eventually reduces the amount of waste that a company produces. The carbon label requires companies to calculate the amount of carbon emissions of a product and display it on the product. There are a few different carbon label options that originated in the U.S.: Certified Carbon Free, Climate Conscious Carbon Label, Green Index Rating, and Pilot Californian Carbon Label. The first carbon label was made by a UK organization called the Carbon Trust and they created the Carbon Reduction Label in 2006. The label requires companies to reduce their carbon emissions by 20% within the first two years following the certification or the label will be taken from them. Initial criticism for the carbon labels was a lack of cohesiveness in terms of standards and depiction on products (Carbon Trust, 2008).

Chart 2 *Five steps to calculating product carbon footprint*


Build process map of product's life cycle
Assess boundaries and materiality
Collect data
Calculate the footprint
Check uncertainty

Of the studies conducted so far on carbon labeling and consumer attitudes it appears that many individuals are interested in making environmentally sound consumer decisions but are confused by the label or desire more information on the label (Guenther & Saunders, 2012). In a study conducted by Guenther et al., looking at consumer preferences for product labeling in the UK and Japan it was found that consumers were most excited about a label pointing to whether or not the package could be recycled, the second was whether a package was eco-friendly, and the last was the display of GHG emissions. The study noted that prior to making assumptions about whether or not individuals would be interested in this type of label it is important to understand the level of public awareness about carbon emissions, climate change, and sustainability (Guenther & Saunders, 2012). If people are not educated about these topics they may be less likely to answer that they would be interested in purchasing products with this label. It is important that companies educate the public about the carbon label and its environmental impacts.

Calculating the carbon footprint of products helps businesses understand how the manufacturing of their products affects carbon emissions and allows businesses to respond to customer's interest in buying low emission products (Carbon Trust, 2008). Carbon emissions are calculated using the PAS 2050, which calculates the GHG associated with the life cycle of the product. A carbon label helps companies understand which parts of the product's life cycle creates the most emissions in order to reduce emissions and save costs (Carbon Trust, 2008). Using a carbon label improves brand reputation and provides customers the opportunity to make better purchasing options. The Code of Good Practice helps businesses understand how to communicate the carbon footprint information to their customers and employees and support claims of emission reduction of a product (Carbon Trust, 2008).

Social

Many consumers care about the environment but do know what they can do to help the cause. The carbon label offers an easy way for the public to make choices that reduce CO2 emissions. In order to get more companies to work with a third party such as the Carbon Trust and put carbon labels on their products, the public should show companies that this is something they care about. Both companies and the public must have incentives to use the carbon label. These incentives include reductions in cost of production for the company and suppliers and thus lower prices for the consumers. With the rise of green labeling products it is apparent that consumers are interested in buying sustainable products from companies that are working towards sustainable best practices.

Environmental

The environmental impact of carbon labels is profound because it requires companies to look closely at their own practices and this review often leads them to identifying the major source of CO2 emissions. Producing virgin raw materials releases a significantly higher amount of CO2 than recycled raw materials. If consumers choose to purchase products with low CO2 emissions, companies will be more likely to switch to only using recycled raw materials thus CO2 emissions and waste will be reduced.

Economic

The main cost associated with carbon labeling is the cost of implementation. The cost depends on the product and the supply chain. The most expensive cost is hiring external consultants, which may be necessary in some cases for large companies. Costs can be cut significant if the process is done internally and verified with carbon trust. Carbon labeling requires up front costs and cooperation from the company and supply chain. In the long-term, the company and often the supplier will be reducing emissions and costs. Carbon Trust notes that once carbon labeling becomes more common and widespread the costs associated with the process of getting a carbon label will decrease (Carbon Trust, 2008).

Political

Currently the organizations certifying companies with a carbon label are private companies. In the case of Carbon Trust, the British government oversees the standards set forth by the Publicly Available Specification 2050. The PAS 2050 outlines a standardized process for measuring the amount of greenhouse gas emissions associated with the manufacturing process from cradle to grave (Carbon Trust, 2008).

Case Study: Walkers Crisps

Walker Crisps are a popular British snack food company and the first company in the world to go through the Carbon Trust's reduction process and put the label on their chips. Post review Walker Crisps found that raw materials and manufacturing were the biggest sources of GHG emissions throughout the crisps life cycle. Walkers reviewed and altered its processes within the production facilities and this resulted in 33% reduction in energy use per 2.2 lb of crisps. The company also reached out to its potato suppliers to collaborate on improved agricultural practices and best practices for storage to reduce emissions. Consumer research group Populus researched how consumers were responding to the carbon labels. 78% of consumers said they had heard of the label and 85% of consumers said they were worried about the environment. 79% of consumers said that the label makes them more aware when they are buying. In July 2007, 17% said they saw the label on a packet of Walkers and by February 2008, 32% said they saw the label on a packet (Pepsico International, 2007).

Looking Back From 2050

U.S. consumers refused to buy products that did not have a carbon label because they no longer wanted to support companies that were not taking responsibility for their waste. This incentivized companies to partner with a third party certifier such as the carbon trust and obtain a label. Companies are privately funding the carbon label through budget adjustments to accommodate long-term use of the carbon label. Through the use of the carbon label, companies have communicated their commitment to reducing waste to their consumers. Companies are required to renew this label every few years and review their production processes.

Strategy #12: Environmental Curriculum

Overview

In order to reach the goal of zero waste by 2050, education programs must be set up in early education so the nation's young people are motivated to reduce waste. Many studies highlight the fact that without public participation and motivation, programs such as single stream recycling become more difficult to execute. People will not be motivated to do their part in recycling if they do not care about an issue i.e., meaning having an emotional attachment to an issue. It is therefore critical that schools in the U.S. implement environmental education programs in early schooling to foster a culture of environmental care. The goal of environmental education is to foster environmental literacy and thus attitude and behavior change. An article by Athman and Monroe notes that awareness of one's surroundings leads to care of the environment and motivation to care for it (Athman & Monroe, 2001). It is important to implement environmental programs that empower students with the knowledge to address environmental issues from a place of personal responsibility (Athman & Monroe, 2001). It is important to note that current environmental education programs often target students in a higher socio-economic class because these programs are in specialized schools or private schools. **Figure 10** suggests that

Enviroschools is facing challenges with providing their program to students of low socioeconomic status. The public school system in the U.S. has a unique opportunity and reach to ensure implementation of environmental education into early childhood years for all students regardless of socio-economic class.

Social

Implementing environmental curriculum is important because it empowers young students to address environmental issues at an earlier age and be prepared to affect change. This can affect families as students have the opportunity to influence practices in the home. As children grow older they can educate co-workers and ensure that best practices are used in business. A ripple effect takes place and these young children are able to raise awareness in all aspects of their lives. This type of responsibility and civic action is important for children and young adults because it creates a sense of “agency”, a feeling that one has the ability to affect positive change. This feeling of self-efficacy can improve mental health and well-being as young adults will not feel as hopeless.

Environmental

Environmental curriculum will foster a culture of environmental stewardship early on that will lead to more pro-environmental behavior in the future. Students will take on projects that directly affect their community giving them a greater sense of purpose and connectedness. These projects can encourage community members of all ages to join together to work on projects. Ultimately this can foster a community that values environmental stewardship. These individuals can then go on to affect change in future communities and circles.

Economic:

For successful implementation of public school curriculum funding resources will need to be allocated from the federal government. There must also be support all the way down to the local government. Currently many of these programs are privately funded and the programs may receive more funding if they are standardized across U.S. public schools.

Political:

In terms of political landscape, the federal government must pass curriculum legislation that incorporates environmental education into early public school education. The public must express strong interest in this type of program so that the program receives federal and municipal support.

Case Study: New Zealand - Enviroschools

Overview

A program in New Zealand called Enviroschools is an example of a sustainable and effective program for children and young adults. Enviroschools, "supports children and young people to plan, design and implement sustainability actions that are important to them and their communities (Enviroschools, 2017)." The program is unique because it is does not just happen for one year and then stop. It continues all the way from early childhood to secondary schooling and beyond. One of the reasons Enviroschools runs so effectively is that many different stakeholders support it. The program has ~100 national and regional partners. Each of these partners has facilitators that work directly with the schools on sustainability initiatives and ensure the program moves forward. Enviroschools now has more than 1,000 schools across New Zealand and provides resources to 260,000 children and young adults (Enviroschools, 2017). **Figure 9** shows that a third of all New Zealand schools are participating in the program. The students work on projects such as waste minimization, biodiversity restoration, food production and use, water conservation and care, sustainable energy use, and ecological buildings (Mardon, Cox, Price, 2015). Students in New Zealand also have the opportunity to learn about the history of the land they live on, giving them a greater appreciation for the indigenous Maori people and the land (Mardon et al., 2015). Enviroschools suggests that the program fosters caring, ethical, and empowered students. The structure of the program is particularly effective as it has support from the federal government all the way down to the local schools.

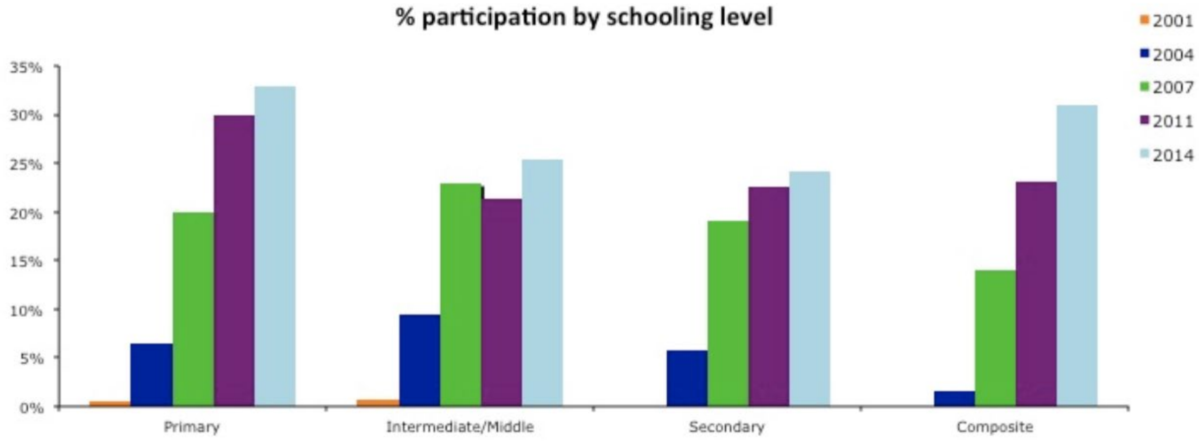


Figure 9: A third of all New Zealand schools are participating in the program and participation from early childhood schools is 5% and growing (Mardon et al., 2015).

Structure of support:

1. National - Public Foundation, Ministry of environment
2. Regional - Regional coordinator and a team of facilitators deliver the Enviroschools program to schools
3. Local - Schools and early childhood education centers sign-up for a long-term sustainability journey with the involvement and support of families and communities.

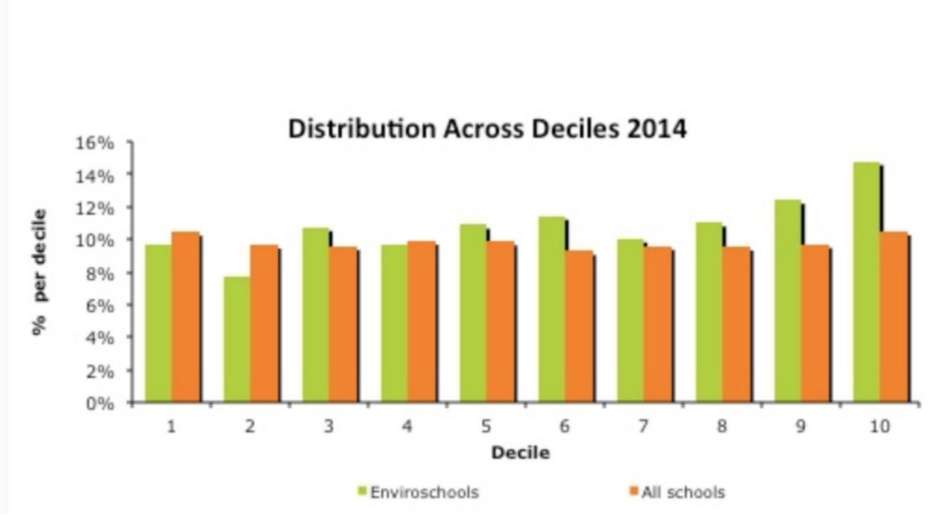


Figure 10: *The Ministry of Education defines deciles as follows: "A school's decile indicates the extent to which the school draws its students from low socioeconomic communities. Decile 1 schools are the 10% of schools with the highest proportion of students from low socioeconomic communities, whereas decile 10 schools are the 10% of schools with the lowest proportion of these students (Mardon et al., 2015)."*

The graph showing the distribution of schools with the lowest and highest proportion of students from low socioeconomic communities indicates that Enviroschools is within the 10% of schools with the lowest proportion of students from low socioeconomic communities. This is an issue with environmental education that is cited by many articles and one that can be alleviated by mandating environmental education programs in public schools in the U.S.

Looking Back From 2050

In the years leading up to the federal government passing legislation to incorporate environmental curriculum into early education, there was a considerable amount of pressure to do so from grassroots organizations, educators, parents, and students. Groups and individuals were upset with the fact that only students who were attending green schools were gaining access to environmental curriculum. The chief complaint was that only students of higher socioeconomic status had access to this type of education. Public school districts wrote letters to the federal government and even drafted legislation for an environmental curriculum. Millions of Americans signed petitions demanding environmental curriculum be incorporated into public schools. Finally the U.S. department of education passed legislation that mandated a standardized environmental education curriculum into public schools. The curriculum is now supported nationally, regionally, and locally. This new curriculum has gained global recognition and the U.S. is a leader in public environmental education.

Strategy #13: Public Outreach Programs

Overview

Many studies have looked at the importance of public outreach programs in getting the public interested and motivated to participate in a certain environmental initiative. It is clear that without reaching out to the public in some mode of delivery it is impossible to get support. A study conducted by Stern et al. (2016) looked at how different modes of communication to the public compared to one another. The survey showed that facilitators feelings of effectiveness of a particular mode were highest for working alongside the public on a project and allowing them to engage tangibly with the project. Also effective was when facilitators acted as an example of how to perform the action being asked of the public, and targeted message content to local problems (Stern, Ardion, Powell, 2016). These findings align with recent research that suggests providing knowledge on its own cannot spark action and that engaging the public in experiential learning projects is more beneficial (Monroe, Andrews, Biedenweg, 2008). Recycling and waste prevention provide a different level of public participation in the sense that waste reduction may require an even larger behavioral change and sometimes cultural shift, therefore emphasizing the importance of educational outreach programs (Margai, 1997). In getting to zero waste by 2050 it is critical that scalable educational outreach programs be implemented in conjunction with municipal waste management programs. This case study shows the effectiveness of an educational outreach program in an area that had significant barriers to success.

Social

Public outreach programs are important socially because they give the public the opportunity to do their part in the program. The public will not be able to actively participate in the way they are being asked to unless they understand what is being asked of them and how to participate. Sustainable public outreach programs will foster pro-environmental behavior and empower individuals to lead their communities.

Environmental

Public outreach is important for the environment because without them recycling and waste initiatives will not receive the support and participation necessary to make a difference. Environmental issues are not problems that can be fixed easily, they require serious commitment and dedication. Public outreach programs can help to ensure the longevity of environmental programs.

Economic

Initially public outreach programs may be costly upfront but this cost can be incorporated into the budget of the program. In the long-term these up front costs will be well worth it as local individuals are trained to carry out the programs. Outreach programs will need funding from the government and private environmental organizations.

Political

In order for successful implementation of public outreach programs, the government must include funding sources for the outreach programs within legislation such as the New York State Solid Waste Management Act. For example this law mandated that municipal governments create waste management plans that involved the residents. This is where it is critically important that municipal governments receive funding to create public outreach programs to empower their local residents. These outreach programs must create accessibility for low-income communities and can only do so with resources to strategically design and implement public education and outreach programs.

Case Study: Waste Reduction Behavior

A study conducted by Florence Lansana Margai looked at how waste reduction behavior changed after an education outreach program in Harlem, New York. The article notes the importance of changing consumer attitudes to encourage people to choose recyclable products and recycle properly so that less waste ends up in landfills (Margai, 1997). The author points out that even if people are interested in implementing waste reduction practices their environment may be determining whether or not this is possible. For example individuals who live in packed urban areas and have a lack of resources to fully integrate these programs will be less successful in waste reduction endeavors (Margai, 1997). In 1988, the New York State Solid Waste Management Act was passed which required all municipalities to create a 10-year waste plan. New York City mandated that residents participate in a waste management program. The city reviewed which parts of the city were successful with the program and found that the one with the lowest recovery rates was in East Harlem, Manhattan, a lower-income community. Many studies suggest that individuals who showed care for the environment were upper or middle class residents and well educated (Buttel & Flinn, 1947; Devall, 1970; Dunlap & Catton, 1979; Tremblay & Dunlap, 1978). This could be explained by a study conducted by Dunlap and Van Liere (1984) which found that care for the environment only correlated with environmental action when people's basic needs were met. Many studies have found that participation in recycling programs improved post implementation of an education outreach program (Burn & Oskamp, 1986; Ham, 1983-1984; Ostman & Parker, 1988).

Margai's study looked at the effectiveness of an environmental program in East Harlem, a community that had several barriers such as low economic-status, poor education, and over crowded housing (Margai, 1997). The program that was implemented worked with people in the housing units, schools and youth programs, small businesses, and community organizations. The program also set up informational sessions for building workers to learn how to help implement waste strategies. The program intervention lasted 9 months and surveys were conducted pre and post intervention. The surveys looked at recycling behavior and waste reduction behavior, knowledge and awareness, levels of care towards the environment, and demographic factors. Post intervention, recycling and waste reduction behavior and knowledge and awareness improved. The demographic survey data initially showed that factors such as age and amount of people living in a household affected participation but after the intervention the effects of these factors were minimized. The study found that individuals in the public housing units had lower participation due to issues with building structures that made it difficult for residents to get their recyclables to the curb. The study noted that empowering local leaders to support residents was critical in keeping participation rates high (Margai, 1997).

Looking Back From 2050

The EPA conducted a national review that found that a majority states were not reinforcing waste management regulations. The EPA suggested that a lack of stringent regulations was endangering resident's health. State governments received pressure from the EPA, residents, and local organizations to review waste management practices and strengthen regulations on residents and companies. The disapproval from various stakeholders prompted states that did not already have a waste management act in place to implement one and required all states to review current regulations. In addition to implementation of waste management acts the municipal governments partnered with local environmental organizations to develop public outreach programs so that residents could learn how to participate in the programs. The municipal governments were incentivized to fund these outreach programs due to the public scrutiny from the EPA and residents regarding public health concerns. A domino effect occurred once a few states announced the launching of public outreach initiatives. The public outreach programs have been successful due to strong local leadership from environmental organizations and the municipal government, as well as incentives for residents to participate in the programs.

Conclusion

This mixture of strategies comes together to form a plan through which the U.S. can produce zero waste by the year 2050. To reach zero waste means that one hundred percent of solid waste is diverted from landfills, incineration, and exportation. There is quite a long way to go before we reach this goal. The nation-wide diversion rate is currently around thirty percent and roughly 31 percent of food produced in the country goes uneaten - only five percent of which is diverted from landfills and incinerators to composting (USEPA, 2017c).

The strategies used in this project include approaches to eliminate biological nutrient waste, recycle technical nutrients, and educate citizens on waste reduction. We address toxic waste as a long term issue to consider because of its dangerous impacts to environmental and human health due to disposal challenges. Our strategy looks at toxic waste source reduction, because in the long run, it is the only complete way to reduce zero toxic waste. As demonstrated by these case studies, there are many initiatives ongoing around the world already that give merit to the efficacy of and provide hope for the implementation of strategies. The biological nutrients, technical nutrients, and education strategies all differed in approach of strategies, but together form a mutually exclusive and completely exhaustive plan through which we can achieve zero waste by 2050. We believe that it would be possible to divert 100% of waste from landfills in the U.S. by 2050 if the 13 strategies in this report were implemented to their full potential.

Our research has affirmed that the EPA's 5 food waste diversion strategies hold the most potential for diverting all biological nutrients from landfills by 2050. By changing the food-waste mindset in the U.S. we could reduce the amount of avoidable food waste that has to be dealt with by altering consumer behavior. By redistributing uneaten but still edible food to people who need it we could both reduce the amount of food that is wasted and alleviate hunger at the same time. We believe that non-profits like Lovin' Spoonfuls will be instrumental in leading the charge on scaling this strategy up to a national level. Once food is no longer fit for human consumption, it can be fed to animals in partnerships like the one between Rutgers and Pinter Farms in order to offset the amount of land and resources used in growing crops for animal feed. When food is no longer fit for animal consumption, it can be composted and the valuable biological nutrients recycled back into the agricultural system as fertilizer like Middlebury College has been doing for decades with its dining hall food scraps. Finally, the lowest quality biological wastes can turned into clean energy via anaerobic digestion at existing municipal wastewater treatment plants like the one in the East Bay Municipal Utility District.

Our technical nutrient strategies are all interrelated and are focused on initiatives that must be taken by all parties currently involved in technical waste production, from technical nutrient extraction to product manufacturing, to household waste. Starting from extraction, the virgin raw materials tax will help change the relative price between recycled raw materials and virgin raw materials, while simultaneously requiring that technical nutrient extractors incorporate the full social and environmental effects currently externalized on local human and animal communities, and on future generations. Product stewardship regulations will ensure designers think about each material they put in a product from a waste and environmental perspective, and will require that manufacturers internalize the cost of disposing of their products. Widespread single stream recycling increases access and ease to the process of recycling in people's day to day lives. These strategies all come together to form what we call " Material Banks," which will operate in sync with an an efficient system. Together, these four technical nutrient strategies will help drive create the closed-loop economy in which the materials in the loop can continuously contribute to economic growth for generations.

As we look to the future we are confident that these strategies have the potential to help us achieve zero waste by 2050. This goal is not possible without commitment from the government, corporations, and the public. In this comprehensive report we outline social, environmental, economic, and political benefits of our waste reduction strategies as well as opportunities and potential barriers. We hope that these strategies educate and prompt key stakeholders to take action. *What can you do as an individual today?*

1. Focus on source reduction. Reduce consumption and waste in your own life and encourage others to do the same.
2. Ask corporations to take responsibility and reduce their waste
3. Write to the local and federal government asking them to implement waste reduction plans
4. Participate in local waste reduction initiatives and engage in public outreach programs.
5. Be an active leader in your community and inspire others to join you

Glossary

Waste: a material that leaves a non-closed-cycle economy, generally to a landfill.

biological nutrient: a nutrient or material that exists naturally in biological cycles and decomposes

technical nutrient: a nutrient or material that does not decompose and cannot be incorporated into biological cycles, such as metals or plastic

source reduction: systems designed to reduce the amount of materials produced; going upstream to prevent unnecessary production.

Closed - loop economy: an economy that minimizes waste and keeps the same materials rotating without adding or subtracting any.

Diversion Rate: The amount of waste diverted from landfills through a number of measures such as composting, recycling, or redistribution.

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